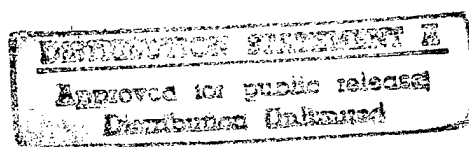


JPRS-JST-90-015  
15 MARCH 1990



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## TRDI Reports Development of New XeCl Laser

906C3824a Tokyo BOEICHO GIJUTSU  
KENKYUHONBU GIHO in Japanese,  
Technical Report No 5541, Jun 89 pp 1-22

[Article by Masakatsu Sugii and Hiroshi Hara, assistant directors general of the Second Research Laboratory, Third Optical Wave Department, Second Research Center, Japanese Defense Agency's Technical Research and Development Institute: "TRDI Technical Report on High-Brightness Corona-Preionized XeCl Discharge Laser"]

### [Text] Summary

A new type of high-brightness corona-preionizer using a segmented  $\text{SrTiO}_3$  dielectric has been developed and it has been applied to the excimer discharge laser for the first time. As a result, a maximum laser efficiency of 2.3 percent has been obtained in an XeCl laser with an output energy of 420 mJ. The laser characteristics obtained with the corona-preionized device were almost the same as those obtained with the UV-spark preionized device using the same laser tube. This indicates that this newly developed high-brightness UV-corona preionizer is useful for the next generation excimer and/or  $\text{CO}_2$  lasers.

### 1. Preface

The rare gas halide excimer laser is a high-output ultraviolet [UV] laser that has recently been attracting considerable attention in the areas of photochemicals and industrial processes, particularly in those areas related to semiconductors. Japan is enthusiastically carrying out research on discharge excitation excimer lasers characterized by high repetition and high average output.<sup>1,2</sup> In addition, it is possible to apply the excimer laser as a blue-green laser, based on the stimulated Raman wavelength conversion, to optical oceanographical fields.<sup>3</sup>

At present, research on excimer lasers is being actively pursued along the following three lines: 1) extending the life of the device, 2) increasing the output, and 3) achieving a high repetition rate. Of the three points, research on preionization technologies related to the first category has been largely completed. Most of the laser products currently on the market employ automatic preionization capacity transfer excitation circuits in which UV spark arrays are used as preionizers. This is because the constitution of such devices is simple and a high degree of efficiency can be readily obtained. However, the UV spark preionization-type laser has two principal defects: First, molecular gas is dissociated optically by the intense UV spark light. In other words, the excimer laser has the burn-up problem common to halogen donors. Second, the life of the laser gas is shorter than that in UV corona preionization and X-ray preionization devices, because of gas contamination caused by sputtering and photochemical reaction.

The UV corona preionization system employs a quiet electric discharge in which the corona discharge itself is

weak and takes the firm sheet. This is a uniform UV preionization system. Accordingly, preionizers can be installed in the vicinity of the main electric discharge electrode and a uniform electric discharge can be realized spatially even if the intensity of the UV light is not increased to the degree that it is in the UV spark system. Therefore, it is possible to solve a number of problems, including the generation of acoustic waves that accompanies preionization discharge, gas contamination and gas dissociation, which have created problems in the UV spark system. The life of the gas used in the corona preionization excimer laser is about 10 times longer than that used in the UV spark system, and a long life of  $10^8$  pulses has already been attained in the XeCl laser.<sup>4</sup> However, the new excimer laser has a drawback in that the laser efficiency is lower than that of the UV spark system. The partial pressure of halogen donors and rare gas must be lowered in order to produce a uniform avalanche discharge. This is because the density of the initial electrons to be generated is small and the intensity of the UV light is low in corona preionization devices in which conventional glass, ceramic, and Kapton film are used in dielectrics. It is believed that these conditions cause a decrease in laser efficiency and output. We have developed a new high-brightness corona-preionizer using an  $\text{SrTiO}_3$  ferroelectric for the first time, and have adopted this system in the discharge excitation excimer laser. As a result, it was confirmed that a high overall efficiency of 2.3 percent (laser output: 420 mJ) can be attained in an XeCl laser. This efficiency is almost the same as the laser efficiency of the UV spark automatic preionization-type XeCl laser obtained by using the same laser tube.

### 2. Experimental Device

Figure 1 shows an excitation circuit diagram of a high-brightness corona-preionizer XeCl laser. The excitation circuit is a capacity transfer type, and the corona preionizer is installed at the back of the upper screen electrode. The laser tube is made of aluminum and has a thickness of 20 millimeters. Experiments can be conducted up to a maximum of 6 atmospheric pressures by using such laser tubes. All the condensers (condenser  $C_1$  of the charging circuit at the primary side, condenser  $C_2$  at the secondary side, and coupling condenser  $C_p$  of the preionizer) are doorknob-type  $\text{SrTiO}_3$  condensers made by TDK Corporation. The synthetic electrostatic capacities of the respective condensers ( $C_1$ ,  $C_2$ , and  $C_p$ ) were measured with an LCR bridge meter (VHP, 4261A). The synthetic electrostatic capacity of  $C_1$  was found to be 82.7 nF, that of  $C_2$  was 80.2 nF, and that of  $C_p$  was 6.4 nF. The main discharge electrode consists of a solid electrode and a screen electrode that use two kinds of stainless punching-wire gauzes with hole diameters of 0.8 and 3.0 millimeters and numerical apertures of 30 and 50 percent, respectively. The thickness of both gauzes is 0.7 mm. The solid electrode is made of stainless steel (316 S.S.) with a width of 40 mm; it is a pseudo-Chang type. A flat portion with a thickness of 12 mm is set in the center of this solid electrode, and the Chang profile of  $K = 0.02$  and  $V = \arccos(-K)$  is processed from

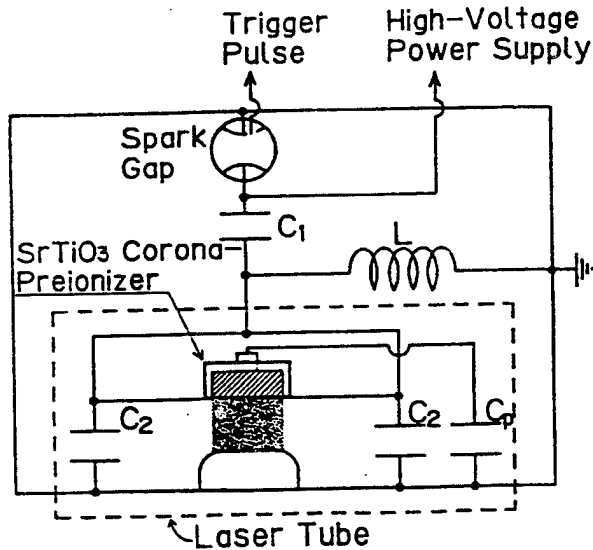


Figure 1. Excitation Circuit Diagram of High Luminescence Corona Preionization XeCl Laser

the end of the flat portion. The electrode interval is 2.2 cm, and the effective discharge length is 60 cm. The discharge width varies depending on charging voltage and charging polarity, but falls within a range of 1.5 to 2.0 cm. Therefore, the discharge volume is 198 to 264 cm<sup>3</sup>. Corona preionization is generated by high frequency corona discharge through a dielectric from the back side of the screen electrode.

We will now discuss the high frequency corona discharge. Assuming that the dielectric is completely press-fitted to the screen electrode, a displacement current ( $I_c$ ) is generated by corona discharge. This is represented by the equation

$$I_c = \epsilon_0 \epsilon_s (S/d) (dV/dt) \dots \dots \dots (1)$$

Where,  $\epsilon_0$ : Dielectric constant in a vacuum  $\epsilon_s$ : Specific dielectric constant of the dielectric S: Effective cross sectional area of the dielectric d: Thickness of the dielectric

All that is necessary is to increase the discharge current ( $I_c$ ) of the corona discharge in order to enhance the intensity of the UV light. As can be seen from equation (1), all that is necessary is to enhance the specific dielectric constant  $\epsilon_s$  or to increase the voltage rise time of  $dV/dt$ . It can be said that the best way is to enhance  $\epsilon_s$ , because the voltage rise time cannot readily be increased without any output switches. We have developed a new corona preionizer using an SrTiO<sub>3</sub> ferroelectric with a specific dielectric constant of 330 at normal temperatures to generate an intensive UV corona. We were the first to apply this system to an XeCl laser.<sup>8</sup> Figure 2 [not reproduced] shows a photograph of the new corona preionizer. The donor knob-type SrTiO<sub>3</sub> ceramic condenser, which has a nominal capacity of 1.7 nF, is made by TDK Corporation and has been put on the market.

The plate electrode on one side of such a ceramic condenser is cut with a diamond cutter. The thirteen pieces obtained from this cutting were arranged in series on the back side of the screen electrode, because long plate SrTiO<sub>3</sub> ferroelectrics cannot be made at present. The screen electrode was connected to the side of the solid electrode through the coupling condenser  $C_p$  to control the displacement current  $I_c$ . The optimum  $C_p$  capacity was 6.4 nF. By calculating the rate of energies put to the preionizer on the basis of the synthetic capacity of the dielectrics and the static capacity values of  $C_2$  and  $C_p$ , it can be seen that 5.8 percent of the charging energies of the secondary side pulse charging circuit are put into the preionizer. The rate of energies put into conventional corona preionizers is about 0.5 percent, because Al<sub>2</sub>O<sub>3</sub> ceramics and Kapton films are used in the dielectrics of these conventional corona preionizers.<sup>6</sup> Therefore, it can be appreciated that the rate of the energies put into the new high-brightness corona-preionizer that we developed is about 11 times that of conventional corona preionizers. This makes it possible to achieve intensive corona discharge. This fact indicates that the energies spent for preionization cannot be ignored.  $C_p$  was positioned so that loop inductance could be minimized, thus electric charge pulse in  $C_p$  can be returned quickly to the main discharging section through the screen electrode.

Figure 3 shows a cross sectional structural drawing of an experimental device. The laser tubes and the metallic materials other than electrodes in the laser tubes are made of aluminum. Also, Teflon was used as an electrical insulating material. The upper portion is a power current at the primary side, and the lower portion is a laser tube. Circuits at the primary and secondary sides are connected by 13 current leading terminals. An experiment was conducted within a charging voltage range of 15 to 35 kilovolts using a spark gap (EG&G, GP-70) as a high voltage switch.

Figure 4 [not reproduced] is a photograph of the light-emitting surface of the high-brightness corona-preionizer. This photograph was overlapped and taken at 4,000 shots in the atmosphere. An energy pulse of one joule per shot was injected into the preionizer. As can be seen from this figure, powerful and almost uniform creeping UV light emission can be realized in the atmosphere. However, it is necessary to pay attention to the fact that non-light-emitting portions exist on the screen electrode, because the dielectric used in this experiment has a cylindrical segment structure. The photograph shown in Figure 4 was taken in a dark room. The light emissions recorded in this photograph are so low that they cannot be recognized by the naked eye unless the photograph is carefully observed. The discharge formation is that of a corona discharge.

The resonator is an internal mirror. It consists of a total reflecting mirror with a radius of curvature of 3 meters and a reflectivity of about 100 percent, and a partial reflecting mirror with a surface reflector of CaF<sub>2</sub> etalon (2D-FLC-10) made by the Acton Research Company.

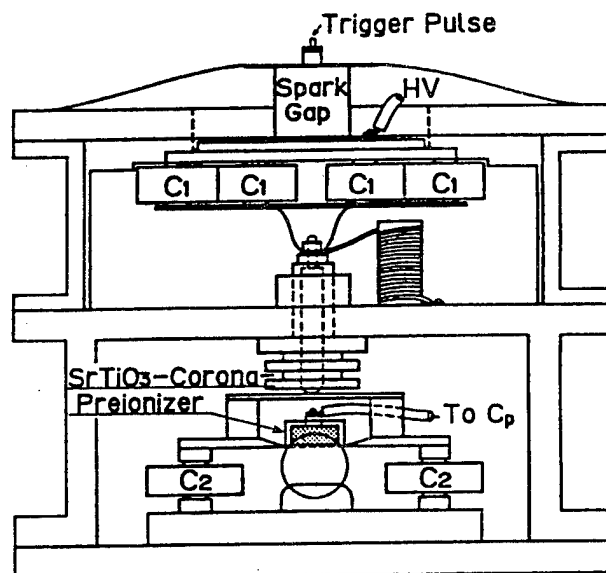


Figure 3. Cross Section Structural Drawing of Experimental Device

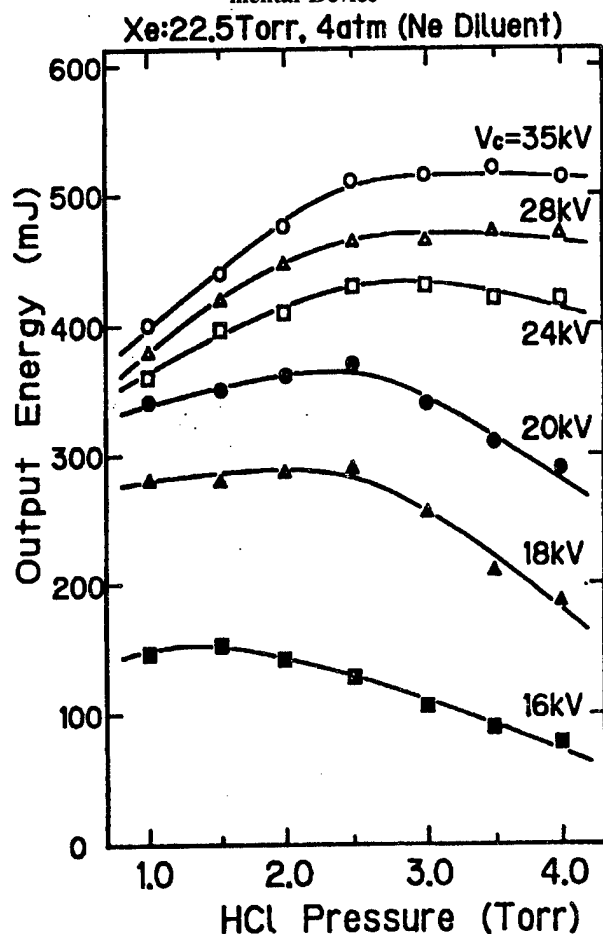


Figure 5. HCl Partial Pressure Dependence of XeCl Laser Output Energies

The total reflecting mirror is coated with multilayer dielectric films. The length of this resonator is 93 centimeters. Laser output energies were measured with joule meters (ED-500 and ED-100A) made by the Gentec Company. Oscillation waveforms were observed with a biplanar-tube (R1193-01) made by Hamamatsu Photonics K.K. and a waveform analyzer (7912AD) made by Telectronics Company.

### 3. Experiment Result and Discussion

First, the mixing ratio and the total pressure of the gas were optimized. Figure 5 shows the dependence of XeCl laser output energies on HCl partial pressure at a total pressure or 4 atmospheres, at Ne dilution, and at a partial Xe pressure of 22.5 Torr. The parameter is a charging voltage. This figure indicates that the optimum partial pressure for HCl is around 2.5 Torr. Also, output decreases with an increase in the partial pressure of HCl at a charging voltage of 20 kilovolts or less. It is thought that this is because, when the charging voltage is low, the intensity of the preionization will be lowered and the uniformity of the discharge will become sensitive to the concentration of electron-adhesive halogen donors. As a result of optimizing the gas mixing ratio, the optimum partial pressure of HCl was 2.5 Torr, and that of Xe was 22.5 Torr.

Next, the total pressure was optimized. Figure 6 shows the result of plotting the total pressure dependence of XeCl laser output energies at a partial HCl pressure of 2.5 Torr, at a partial Xe pressure of 22.5 Torr, and at Ne dilution using the charging voltage as a parameter. As can be seen from this figure, the maximum output energy was 600 mJ at a total pressure of 5 atmospheres. However, it should be noted that the optimum total pressure is 4.0 to 4.5 atmospheres from the standpoint of laser efficiency.

Input-output [I/O] characteristics were measured at the gas mixing ratio optimized through the above method. Figure 7 shows the charging voltage dependence of the overall efficiency and XeCl laser output energies at a total pressure of 4 atmospheres, at Ne dilution, at a partial Xe pressure of 22.5 Torr, and at a partial HCl pressure of 2.5 Torr. This figure depicts the experimental results for output energy characteristics where two screen electrodes with numerical apertures of 30 and 50 percent were used. As can be seen from Figure 7, laser output characteristics in the case where a screen electrode with a numerical aperture of 30 percent is used are higher than those in the case where a numerical aperture of 50 percent is used. This reason for this is as follows. As can be seen from Figure 4, the screen electrode does not have uniform surface light emission. This is because the corona preionizer used in the experiment had a cylindrical segment structure. Therefore, when the numerical aperture is excessively enlarged, the contrast between the intensity of the UV light from the light-emitting portion and that from the non-light-emitting portion will be increased. As a result, the discharge state is liable to become a spotty glow discharge with a concentration where there is a high density of initial electrons, and

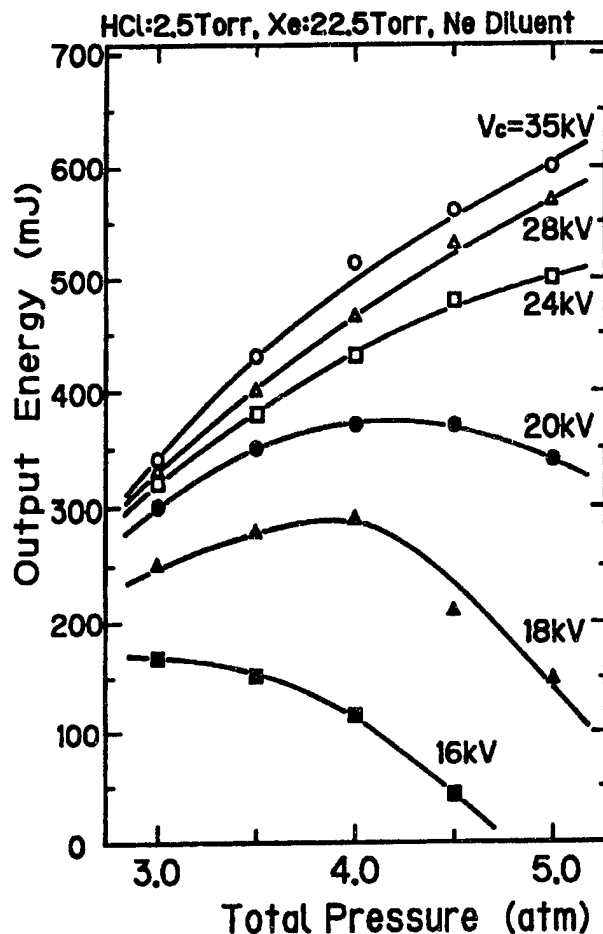


Figure 6. Total Pressure Dependence of XeCl Laser Output Energies

effective excitation volumes will decrease. A detailed discussion of the spatial uniformity of this discharge will be given later on.

When the numerical aperture and the charging voltage of the screen electron were 30 percent and 19 kilovolts in this experiment, a laser output of 350 mJ was obtained at an overall efficiency of 2.35 percent. Also, the maximum output was 500 mJ at a charging voltage of 35 kilovolts. In the case where the UV spark automatic preionization capacity transfer was effected by using the same laser tube, a laser output of 380 mJ was obtained at an overall efficiency of 2.4 percent. The laser efficiency obtained from the high-brightness corona-preionization system is almost the same as that obtained from the UV spark system. This fact indicates that the high-brightness corona-preionizer we have developed works effectively.

When the charging polarity of a corona preionization-type pulse laser is changed, how are laser characteristics changed? No detailed report on this change has been made up to now. Therefore, no design guidelines have been provided concerning which polarity should be

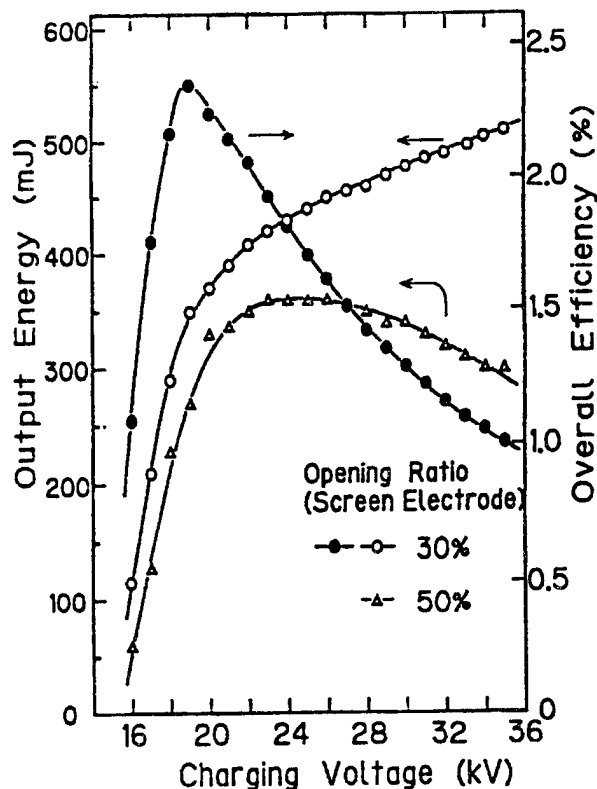


Figure 7. Charging Voltage Dependence of Overall Efficiency and XeCl Laser Output Energies

selected for the screen electrode. Of course, the preionizer is set on this screen electrode. The authors, et al., have made a comparison among laser characteristics obtained when the charging polarity of the charging circuit at the primary side is changed in order to clarify this question. Figure 8 shows the charging voltage dependence of laser output energies in the case where the charging polarity of the charging circuit at the primary side is changed. The experimental conditions were as follows: 1) the partial pressure of HCl was 2.5 Torr and that of Xe was 22.5 Torr; 2) the total pressure was 4.5 atmospheres at Ne dilution; and 3) the numerical aperture of the screen electrode was 30 percent. It is necessary to pay attention to the fact that the screen electrode corresponds to the cathode for a + charge while the solid electrode corresponds to the cathode for a - charge. As can be seen from Figure 8, when the charging voltage is 24 kilovolts or less, laser output in the case of the + charge is higher than that in the case of the - charge. However, when the charging voltage is 24 kilovolts or more, laser output in the case of the - charge is higher than that in the case of the + charge.

Figure 9 shows the effects of changing the characteristics shown in Figure 8 on the relationship between charging voltage and overall efficiency. A maximum overall efficiency of 2.3 percent was obtained from the + charge at a charging voltage of 21 kilovolts and a laser output of

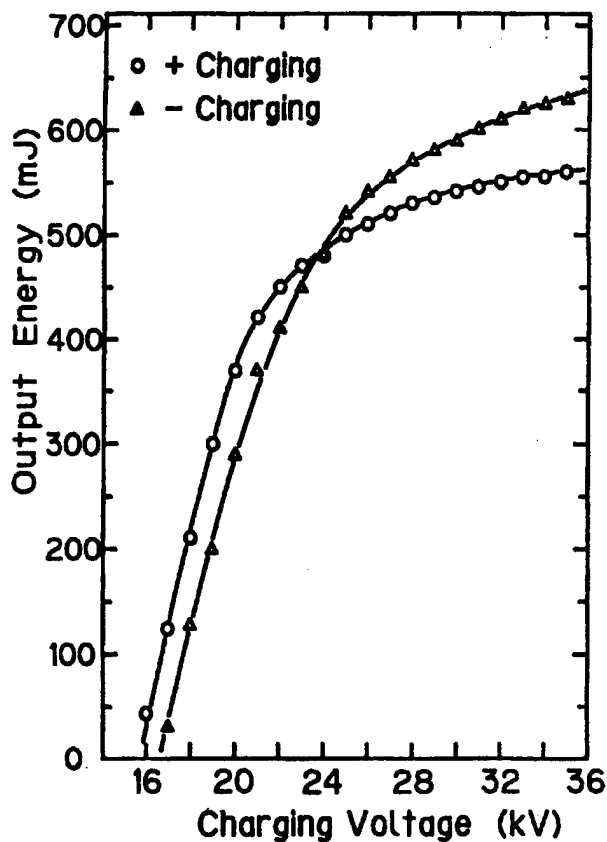


Figure 8. Charging Voltage Dependence of Laser Output Energies in the Case Where Charging Polarity at the Primary Side Charging Circuit Is Regarded as a Parameter

420 mJ. A figure of 2.05 percent was obtained from the - charge at a charging voltage of 23 kilovolts. Therefore, it can be seen that maximum overall efficiency is greater for a + charge than for a - charge.

It is believed that when these charging polarities are changed, the difference between the characteristics of the laser output and those for overall efficiency depends mainly on the charging state. For this reason, the authors, et al., have made a comparison of the differences among laser characteristics in the case where the charging polarity at the primary side is changed, and have discussed the results obtained from this comparison while quantitatively evaluating the discharge spatial uniformity obtained from the measurement of the near-field patterns of laser beams. With regard to this measurement, the resonator of a flat-flat mirror is structured so that these near-field patterns directly reflect discharge patterns. An aperture with a diameter of 0.5 mm was inserted<sup>7</sup> into a place 2 cm from the output mirror, and laser beams passing through this aperture were measured with a joule meter (ED-100A) made by Gentec. The aperture and the joule meter were fixed on the same XYZ grid. Near-field patterns were measured while

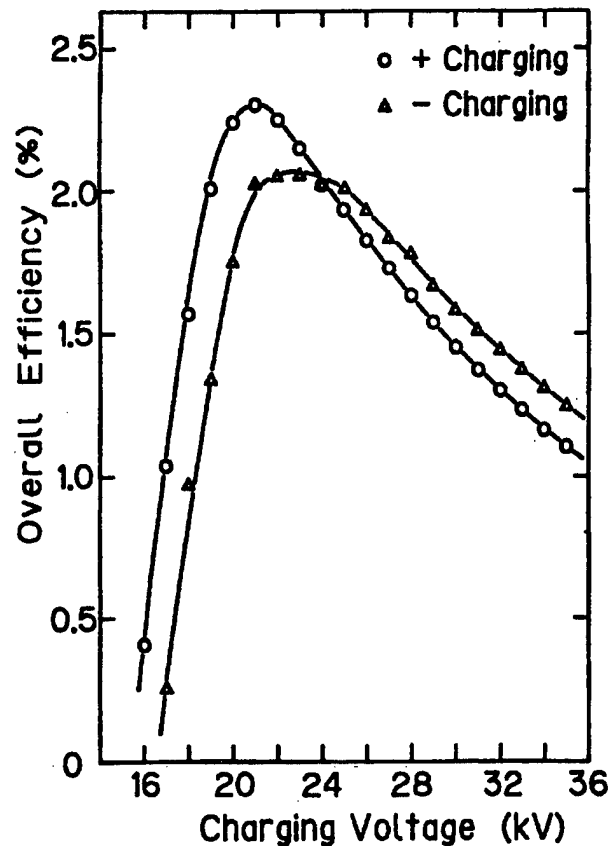


Figure 9. Charging Voltage Dependence on Overall Efficiency When Charging Polarity at the Primary Side Charging Circuit Is Regarded as a Parameter

scanning the aperture and the joule meter in the horizontal and vertical directions.

Figure 10 shows near-field patterns in the horizontal direction in the case of the + charge. Charging voltage is regarded as a parameter. As can be seen from this figure, laser beam patterns slightly incline to the right side at a low charging voltage of 20 kilovolts. Also, the full width at half the maximum output of the beams is narrower than that obtained when using a high charging voltage of 32 kilovolts. However, such output beams are widened, and symmetrical and almost uniform beam patterns are obtained in accordance with an increase in charging voltage. This fact indicates that the discharge uniformity in the horizontal direction improves with a rise in charging voltage.

In the same way, Figure 11 shows near-field patterns in the horizontal direction in the case of the - charge. As can be seen from this figure, symmetrical and bell-shaped uniform output beam patterns were obtained even at charging voltages of 20 to 32 kilovolts in the case of the - charge. This fact indicates that symmetrical and uniform avalanche discharge is obtained extending over a range from low to high charging voltages.

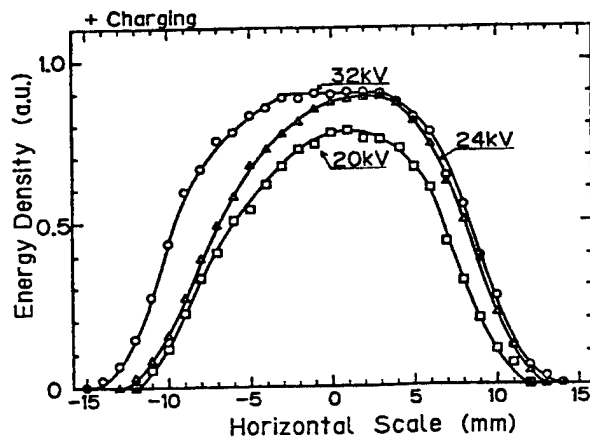


Figure 10. Near-Field Pattern in the Horizontal Direction for a + Charge

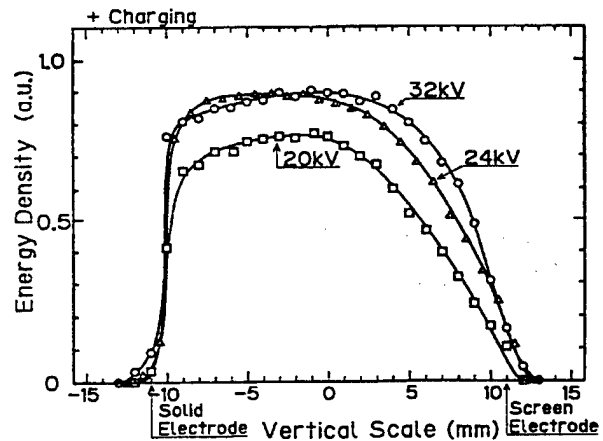


Figure 12. Near-Field Pattern in the Vertical Direction for a + Charge

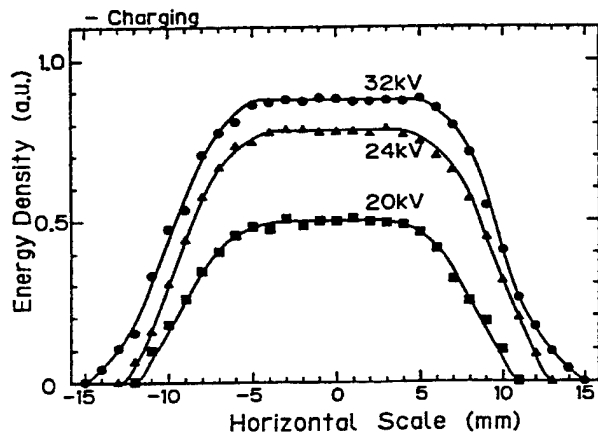


Figure 11. Near-Field Pattern in the Horizontal Direction for a - Charge

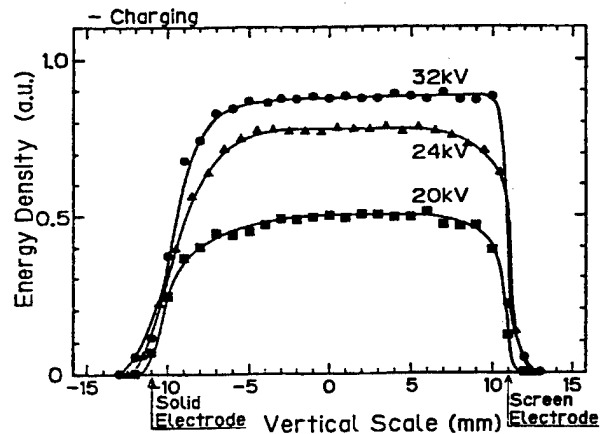


Figure 13. Near-Field Pattern in the Vertical Direction for a - Charge

Next, in the same way, near-field patterns were measured in the vertical direction for + and - charges. Figure 12 shows the near-field patterns in the vertical direction for a + charge. It is necessary to note that the screen electrode on the right side turns into a cathode when there is a + charge. This figure indicates that the building up of the intensity of the laser light in the vicinity of the cathode is improved to some extent, together with a rise in the charging voltage, when there is a + charge. But even if the charging voltage is changed, there is little change in the asymmetrical beam patterns in the vicinity of the cathode where they are weak, and the intensity of light is high in an area extending from the center to the anode.

In the same way, Figure 13 shows near-field patterns in the vertical direction when there is a - charge. In this case it is necessary to note that the solid electrode on the left side turns into a cathode. As can be seen from this figure, the building up of the intensity of the laser light in the vicinity of the cathode is slower to some extent than that in the vicinity of the anode, but trapezoidal and uniform

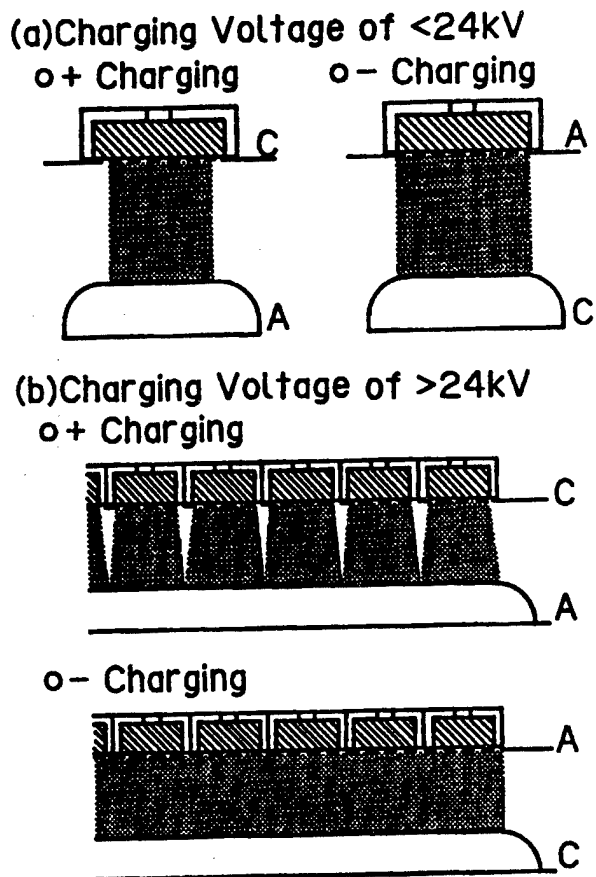
beam patterns are obtained at any charging voltage. These beam patterns are also symmetrical in the vertical direction.

The measurement of near-field laser beam patterns as described above has demonstrated that the spatial uniformity of laser beams is better when there is a - charge (solid electrodes changes to a cathode) than when there is a + charge. This fact clearly indicates that the change from a solid electrode to a cathode will produce a discharge with excellent spatial uniformity.

We will now discuss changes in laser output and in the characteristics of the overall efficiency caused changes in these charging polarities in terms of the spatial uniformity of discharge. The avalanche discharge in excimer laser media is achieved at high pressures, including halogen donors with electron-adhesiveness. It is characterized by low plasma impedance and poor uniformity of discharge. Therefore, in order to achieve an arc-free avalanche discharge, it is necessary to determine the required degree of uniformity and the density of the initial electrons to be supplied to the cathode



electrodes.<sup>7</sup> The experimental results described above indicate that better laser characteristics can be obtained from the + charge (change of screen electrode to cathode) in charging voltages of 24 kilovolts or less. The postulated reasons for this are as follows: In the case of the + charge (change of screen electrode to cathode), even if the density of the initial electrons is low on the cathode electrode, the charging voltage is high, and the distribution area of the ionized initial electrons is smaller than that in the case of the - charge, because preionization is generated only from the back side of the cathode electrode. For this reason, as can be seen from the measurement of near-field patterns, when the charging voltage is low, the discharging width for the + charge is narrower than that for the - charge. Figure 14(a) shows the state of change of the discharging width caused by the difference of charging polarities. In this way, almost optimum excitation density can be realized at low charging voltages of 24 kilovolts or less for the + charge, and it can be said that this in turn results in a high degree of laser efficiency.



**Figure 14. Outline Drawing of Change of Electric Discharge Caused by Differences in Charging Polarities (a) Electric discharging state seen from end face at charging voltage of 24 kV or less; (b) Electric discharging state seen from side at charging voltage of 24 kV or more [Note: C=cathode; A=anode]**

Next, we will discuss the case where the charging voltage is 24 kilovolts or more. When the charging voltage is 24 kilovolts or more, the laser characteristics produced when there was a - charge (change of solid electrode to cathode) were better than those produced when there was a + charge. The screen electrode does not emit surface light uniformly. This is because, as previously mentioned, the dielectric of the corona preionizer used in this experiment has a cylindrical segment structure. It is believed, therefore, that when there is a + charge (change of screen electrode to cathode), the uniformity of electron distribution on the cathode is lost in proportion to a rise in charging voltage. A spotty discharge occurs because of the concentration of electrons into high-density sections and laser output becomes saturated. Figure 14(b) shows an outline drawing of a discharge state (viewed from the side) on the basis of the differences in charging polarities. It is thought that a uniform distribution of electrons on the cathode electrode is not lost even if the charging voltage increases. This fact is reflected in the spatial uniformity of discharges and high laser output. This comes about because the cathode electrode is irradiated with UV rays at a certain angle in the case of the - charge (change of the solid electrode to a cathode).

To sum up, in order to achieve a spatially uniform discharge at any charging voltage in an XeCl laser using the high-brightness corona preionizer that we developed, we found that it is better to change the solid electrode to a cathode. We also learned that this change has little effect in terms of erosion on the electrodes due to ion impacts. Therefore, it is given as a conclusion that in designing excimer laser equipment with corona preionization and high repetition, it is better to design such equipment so that the solid electrode becomes a cathode even if efficiency decreases to some extent.

Next, we will compare the laser characteristics of this device with those of the UV spark automatic preionization XeCl laser and those using traditional corona preionization systems. Table 1 provides an outline of these laser devices and laser characteristics. A maximum overall efficiency of 2.3 percent has been obtained up to this point at an output of 420 mJ from the device developed by authors, et al. The laser pulse width of this device was 25 ns. In 1985, Ernst, et al., obtained an output of 520 mJ from the creeping UV corona preionization PFL driving-type XeCl laser at an overall efficiency of 2.5 percent.<sup>8</sup> Recently, an overall efficiency of four percent has been obtained from the XeCl laser of the UV corona preionization photo-switching system,<sup>9</sup> but the maximum overall efficiency that has been obtained up to now comes from the capacity transfer XeCl laser of the type developed by Ernst, et al. However, this laser cannot be used to circulate gas at high speeds and is unsuitable for high-repetition operations. This is because preionizations are carried out via creeping corona discharges from both sides of the main discharge electrodes. Also, the operating pressure is very high, up to 9.9 atmospheres. In 1985, Butcher, et al., developed an XeCl laser that used an automatic corona preionization system from the backside of the mesh electrodes in the same way as the device developed by authors and obtained an average

output of 300 watts at a repeat frequency of 500 hertz.<sup>4</sup> The maximum overall efficiency at that time was reported to be 2.0 percent, but an overall efficiency of 2.3 percent obtained

from this experiment exceeds the above maximum overall efficiency, and this 2.3 percent figure represents the highest overall efficiency obtained from this type of laser.

**Table 1.**  
**Comparison Between Characteristics of High-Luminance Corona-Preionization XeCl Laser and Those of Existing Automatic Preionization Capacity Transferring-Type XeCl Lasers**

	Present Work	Ernst, et al., (1985)	Butcher, et al., (1984)	Miyazaki, et al., (1985)
Preionizer	UV-Corona	UV-Corona	UV-Corona	UV-Sparks
Gas mixture	HCl/Xe/Ne=2.5/22.5/3395 at 4.5 atm	HCl/Xe/Ne=4.5/10.5/7487 at 9.9 atm	—	HCl/Xe/Ne=2.0/40.0/3000 at 4.0 atm
Excitation circuit	Capacitor transfer	Water-PFL	Capacitor transfer	Capacitor transfer
Active volume	1.6 x 2.2 x 60 (cm <sup>3</sup> )	1.5 x 1.4 x 40 (cm <sup>3</sup> )	3.3 x 2.5 x 75 (cm <sup>3</sup> )	1.2 x 1.8 x 54 (cm <sup>3</sup> )
Charged energy	18.2J (21 kV)	20.5J (17 kV)	—	9.6J (18 kV)
XeCl laser energy	0.42J	0.52J	0.5J (maximum)	0.28J
Overall efficiency	2.3%	2.5%	2.0% (maximum)	2.9%
Pulse width (FWHM)	25 ns	55 ns	30 ns	20 ns
Remarks	Intense UV-corona preionization behind mesh electrode	Surface UV-corona preionization beside main electrodes	Corona preionization behind the mesh electrode	Automatic UV-spark array preionization

We will now compare conventional UV spark automatic preionization capacity transfer-type XeCl laser characteristics and the characteristics of the laser produced by the device we developed. Miyazaki, et al., have obtained an output of 280 mJ at an overall efficiency of 2.9 percent from the UV spark preionization XeCl laser. This output is the highest output obtained from an automatic preionization capacity transfer-type XeCl laser.<sup>7,10</sup> Incidentally, it should be noted that the maximum efficiency obtained from our device is very close to that obtained from this UV spark system. The corona-preionization system is very advantageous given that the life of the gas is longer than that of the UV spark system. It is believed that the high-brightness SrTiO<sub>3</sub> corona-preionizer we have developed will be effective as a next-generation preionizer for excimer and CO<sub>2</sub> lasers.

#### 4. Conclusion

We have developed a new high-brightness corona-preionizer using SrTiO<sub>3</sub> dielectrics for the first time, and have adopted this device for use in a discharge excitation XeCl laser. We have obtained a laser output of 420 mJ at a high overall efficiency of 2.3 percent. This overall efficiency is almost the same as the laser efficiency of the UV spark automatic preionization capacity transfer-type XeCl laser obtained by using the same laser tube. The screen electrode does not exhibit uniform surface light emission, because the dielectric used in this experiment has a cylindrical segment structure. Operations with higher efficiency can be expected, because the uniformity of this surface light emission can be improved by replacing the dielectric with a sheet-type dielectric. Based on these facts it can be concluded that the high-brightness corona-preionizer we have developed will be effective as a next-generation preionizer for excimer and CO<sub>2</sub> lasers.

Also, we have made a comparative analysis of the changes in laser characteristics due to the differences in charging polarities from the standpoint of the spatial uniformity of discharge. As a result, we have determined that it is better to change the solid electrode to a cathode, even if efficiency decreases to some extent, because of the advantages derived in terms of uniformity of discharge and electrode erosion.

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**JAERI Aims for HTTR Criticality by FY95**

90CF0115A Tokyo NIHON GENSIRYOKU  
GAKKAISHI in Japanese 30 Jul 89 pp 28-31

[Written by Shusaku Shiozawa, Japan Atomic Energy Research Institute]

[Text] **5. High-Temperature Gas Reactor (High-Temperature Engineering Test Research Reactor)**

The high-temperature engineering test research reactor (HTTR), Japan's first high-temperature gas reactor, is a nuclear reactor for the specific purpose of carrying out test research to establish the base for and to try to pursue high-temperature gas reactor technology as well as all types of advanced high-temperature engineering research. Japan Atomic Energy Research Institute (JAERI) is currently completing the preparation for its construction with the aim to achieve HTTR criticality by FY95.

(1) Outline of Atomic Reactor

The HTTR is a graphite deceleration-He gas cooling reactor using coated fuel particles. Its thermal output is designed for 30 MW. The reactor's outlet coolant temperature is 850°C at normal operation, and 950°C at high-temperature test operation. The construction site is expected to be on the site of JAERI's Oarai Laboratory, on the southside of JMTR. The basic specifications of the reactor are listed in Table 11.

As shown in Figure 24, the reactor consists of the reactor pressure vessel, fuel assembly, reflector, inside-reactor structures and control rods. The reactor's core is constructed roughly in a cylindrical shape by placing control

rod guiding block over hexagonal column-shaped fuel assembly, and is surrounded by reflectors both in the radial and axial directions. The crosssection of the core is shown in Figure 25.

The fuel assembly is of the pin-in-block type on which R&D has been done in Japan. As shown in Figure 26 graphs, the fuel assembly has graphite blocks with holes into which fuel rods are inserted. The fuel rods are made

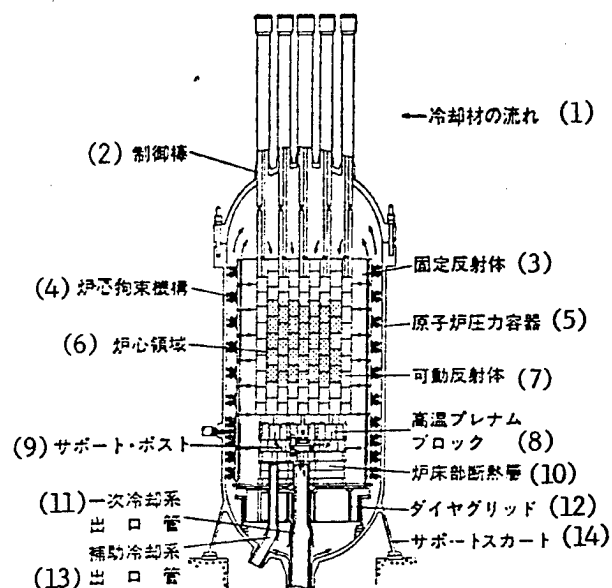


Figure 24. Crosssection of HTTR

Key:—1. Coolant's flow—2. Control rod—3. Fixed reflector—4. Reactor core restraining mechanism—5. Nuclear reactor pressure vessel—6. Reactor core region—7. Movable reflector—8. High-temperature plenum block—9. Support post—10. Reactor base insulating layer—11. Primary coolant outlet pipe—12. Diamond grid—13. Auxiliary coolant outlet pipe—14. Support skirt

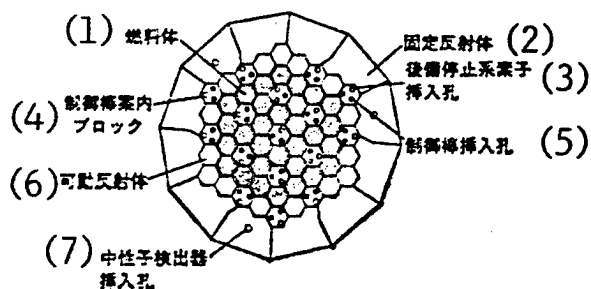


Figure 25. HTTR Reactor Core Crosssection

Key:—1. Fuel assembly—2. Fixed reflector—3. Reserve stopper device insertion hole—4. Control rod guiding block—5. Control rod insertion hole—6. Movable reflector—7. Neutron detector insertion hole

Table 11. Basic Specifications of HTTR

Item	Specifications
Reactor Thermal Output	30 MW
Coolant	He Gas
Reactor Inlet/	395/850°C (at regular operation)
Outlet Cooling Temperature	about 950°C (at high-temp. test operation)
Primary Cooling Pressure	40 atm.
Reactor Core Material	Graphite
Reactor Core Effective Height	2.9 m
Reactor Core Equivalent Diameter	2.3 m
Output Density	2.5 MW/m <sup>3</sup>
Fuel	UO <sub>2</sub> Coated particles/graphite disp. type
Degree of U Concentration	Three to 10 percent (Avg. six percent)
Fuel Assembly Format	Block type
Reactor Pressure Vessel	Steel-made (2 ¼ Cr-1 Mo Steel)
Number of Main Cooling Circuits	One loop (intermediate heat exchange and pressurized water cooler)

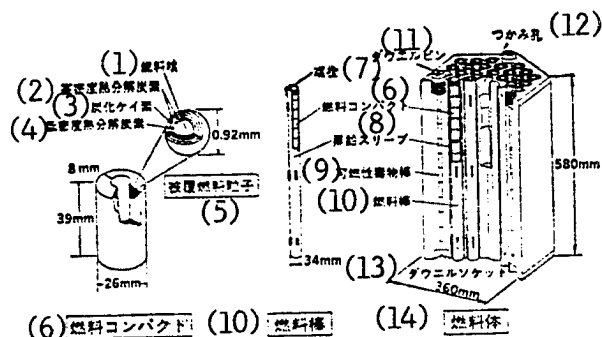


Figure 26. Rough Sketch of Fuel Assembly Structure

Key:—1. Fuel core—2. High-density pyrolyzable carbon—3. Silicon carbide—4. Low-density pyrolyzable carbon—5. Covered fuel particle—6. Compacted fuel—7. End cap—8. Graphite sleeve—9. Combustible poison rod—10. Fuel rod—11. Dowel pin—12. Grabbing hole—13. Dowell socket—14. Fuel assembly

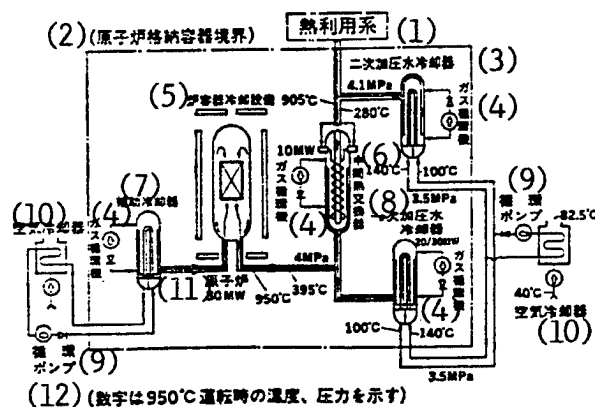


Figure 27. HTTR's Cooling System Design

Key: —1. Heat Utilization System—2. (Nuclear Reactor Housing Borderline)—3. Secondary pressurized water cooler—4. Gas circulator—5. Reactor vessel cooling facility—6. Interim heat exchanger—7. Auxiliary cooler—8. Primary pressurized water cooler—9. Circulation pump—10. Air cooler—11. Nuclear reactor 30MW—12. (Numbers indicate temperature and pressure in operations at 950°C)

by packing compacted fuel, which are made by calcining coated fuel particles dispersed in graphite powder, in graphite sleeves.

The reactivity of the nuclear reactor is controlled by adjusting the position of control rods. In case any control rod cannot be inserted, the operation of the nuclear reactor can be stopped safely and surely by drop-inserting pellets, made by calcining boron carbide and graphite, into reserve shutdown device insertion holes.

The reactor's cooling system consists of the main cooling system, the auxiliary cooling system and the reactor vessel

cooling system. Under normal operating conditions, heat evolved at the reactor's core is taken out of the reactor by the interim heat exchange and the primary pressurized water cooler of the main cooling system, and is ultimately released to the atmosphere via the air cooler. In the future, a test device for nuclear heat utilization will be connected to the secondary side of the interim heat exchange. The auxiliary cooling system is used when the circulator of the main cooling system is out of order. The reactor vessel cooling system is used to remove residual heat of the reactor when the coolant's circulation circuit cannot be formed due to pipe breakage in the main cooling system. The design of the cooling system is schematically shown in Figure 27.

## (2) Functions and Objectives of HTTR

HTTR will serve for demonstration tests and comprehensive performance tests of high-temperature gas reactor elemental technologies, that have previously been accumulated and integrated in this reactor, to establish a technological base for high-temperature gas reactors. It will also serve for advanced basic research concerning high temperature and high-temperature gas reactor technology improvement aiming for future practical applications. The objectives of main HTTR test and research projects are described below.

### (i) Establishment of high-temperature gas reactor technological base

The comprehensive characteristics of a high-temperature gas reactor as a system will be clarified through research concerning nuclear-thermal-kinetic properties, plant operation control characteristics, fuel combustion characteristics and the release behavior of fission products (FP). A technological base will be established concerning the stable removal of high-temperature heat out of the nuclear reactor through test operations at a reactor outlet coolant temperature of 950°C.

### (ii) Improvement of high-temperature gas reactor technology

In order to upgrade high-temperature gas reactor technology for gaining the reactor's better performance and more economical operation, studies will be conducted on the sophistication of elemental technologies, the improvement of reactor core characteristics and the establishment of high-temperature heat utilization technology. Demonstration tests will also be carried out for safety unique to high-temperature gas reactors.

### (iii) Advanced basic research concerning high temperature

Advanced basic research projects will include material irradiation tests at high temperatures up to 1,100°C; the development of nuclear reactor instrumentation technology; basic research concerning Th fuel; developmental research concerning a nuclear fusion reactor; and test research concerning radiochemistry.

## (1) 第12表 HTTR における照射試験の概要

(2) 照射領域	(3) 試料最大寸法 (cm)	(4) 照射温度† (°C)	(5) 照射試験の内容
(6) 中央カラム試験燃料	1 ブロック (平均 36×58)	400~1,100	(8) 燃料限界照射試験, 材料照射試験
(10) 可動反射体 A	φ25×50	400~ 800	(9) 高性能燃料照射試験 (11) 燃料キャプセル照射試験 材料照射試験
(12) 可動反射体 B	φ13×50	400~ 800	(11) トリチウム連続回収, 水素製造試験 材料照射試験, トリチウムパッチ
(14) 固定反射体	φ10×300	400~ 600	(13) 回収試験 材料照射試験 (15)

(21) 最大熱中性子束:  $5 \times 10^{17} n/m^2 \cdot s$ , 最大高速中性子束:  $2 \times 10^{17} n/m^2 \cdot s$

(23) 雰囲気冷却材温度 (22)

Key:—1. Table 12. Outline for Irradiation Tests with HTTR—2. Irradiation Region—3. Sample Maximum Dimension (cm)—4. Irradiation Temperature\* (°C)—5. Nature of Irradiation Test—6. Central Column Test-Fuel—7. One block (average diameter 36 x 58)—8. Fuel critical irradiation test and material irradiation test—9. High performance fuel irradiation test—10. Movable Reflector A—11. Fuel capsule irradiation test, material irradiation test, tritium continuous recovery and hydrogen production test—12. Movable Reflector B—13. Material irradiation test and tritium batch recovery test—14. Fixed Reflector—15. Material irradiation test—16. Test-fuel loading region—17. Central column loading hole—18. Movable reflector loading hole B—19. Fixed reflector loading hole—20. Movable reflector loading hole A—21. Maximum heat neutron flux—22. Maximum high-speed neutron flux—23. \*Atmosphere coolant temperature

## (3) Irradiation Test Plan

Irradiation tests with HTTR are unique in that a large irradiation region is possible and high-temperature irradiation can be performed in a range from 400 to 1,100°C. The outline of irradiation tests is in Table 12.

Irradiation tests are roughly classified as follows depending on the test objective and the sample type.

## (i) Fuel Critical Irradiation Test

As one of the most unique irradiation tests with HTTR, it is planned to use fuel samples as large as the actual fuel assembly in fuel critical irradiation tests, in order to clarify the comprehensive breakdown behavior and the post-breakdown effects of the high-temperature gas reactor fuel. Previously, the clarification of the breakdown behavior of the high-temperature gas reactor fuel has been attempted only with a unit of fuel rod, at best, which was tested by heating outside the reactor or in capsule irradiation tests. Thus, tests on the scale of the fuel assembly inside an actual reactor have never been attempted anywhere in the world. This test is expected to primarily yield the following information which is not readily obtainable from tests with a fuel rod or less:

(a) relationships of fuel breakdown and temperature distribution, output distribution and combustion distribution of fuel rods in the reactor,

(b) the proof that fuel breakdown will not propagate in the case of an accident, and

(c) the appropriateness for the release and shift behavior of FP at the time of fuel breakdown and for the fuel breakdown surveillance system.

By this test, the comprehensive breakdown behavior and its effects of a high-temperature gas reactor fuel will be clarified, and ultimately, test results will be used for the development of high-performance fuels and the demonstration of safety unique to high-temperature gas reactors.

In this irradiation test, the coating layer of a fuel sample's particles is damaged by either restricting the coolant's flow rate or elevating the output for the fuel sample.

From the safety standpoint, the uniqueness of this test is the release of a little FP from a fuel sample to the primary coolant according to the purpose of the tests. Therefore, considerations are given to establish separate safety evaluation standards for this test concerning fuel samples and experimental facility in order to secure ample safety for the reactor. Specifically, this test is designed to restrict the quantity and loading position of a fuel sample so as not to give any significant effects to the reactor core fuel, and also to detect FP released from the fuel sample by a fuel breakdown detector and a primary coolant radioactivity surveillance device.

## (ii) Irradiation Test for High-Performance Fuels

For the purpose of developing high-performance fuels for high-temperature gas reactors, that can realize high-output density and high combustibility, an actual-scale test-fuel assembly is loaded in one section of the fuel region and irradiated to prove the good conditions of the fuel assembly.

The test-fuel assembly under consideration can be a new type fuel assembly consisting of compacted fuel/graphite sleeve-integrated type fuel elements aiming for an output

density of approximately 20 MW/m<sup>3</sup> and a combustion degree of approximately 200 GWd/t. Or it can be a spherical fuel assembly (a pebble-type fuel assembly) used in West Germany, or an assembly of Th fuel particles. In contrast with the fuel critical irradiation test described in (i) above, which aims for clarifying breakdown limits by intentionally damaging a fuel under severe conditions, this test aims for proving the wholesomeness of a fuel assembly without damaging the fuel but by primarily checking the fuel's irradiation behavior, FP maintenance property and thermal conductance property.

### (iii) Fuel Capsule Irradiation Test

Advanced basic research will be carried out on high-temperature gas reactor fuels by irradiating fuel samples in a capsule; the samples being of the scale of a high-temperature gas reactor fuel rod or compacted fuel. This test permits the settling (variable) of test conditions, such as temperature, pressure and atmosphere gas, depending on the capsule to be irradiated and the test objective, to continuously measure the emission of FP from a fuel sample by attaching a sweep tube to the capsule to be irradiated, and to increase the fuel sample

temperature up to 2,500°C. A conceptual diagram of a capsule for irradiation is shown in Figure 28.

### (iv) Material Irradiation Test

Taking advantage of the HTTR's characteristic of enabling high-temperature irradiation with a large test piece, the following material tests are planned.

(a) tests to clarify high-temperature irradiation properties, such as creep under irradiation, for ceramic materials,

(b) tests concerning post-irradiation fatigue dynamics and irradiation-caused creep tests under the real atmosphere for large test pieces of nuclear reactor vessel structural materials and heat-resistant metals, and

(c) tests to find out the heat-resistant and irradiation-resistant properties of the reactor's instrumentation devices by inserting detectors of temperature, pressure, flow rate, neutron flux and dimension change, inside the reactor for the purpose of developing instrumentation devices that will be usable under extreme environment.

A conceptual diagram of a capsule for material creep irradiation tests is shown in Figure 29.

### (v) Others

Tests will be conducted to study tritium formation conditions and recovery technology by irradiating a tritium breeding target (such as LiO<sub>2</sub>, LiAlO<sub>2</sub>) at a high temperature and recovering formed tritium either continuously or batch-wise. Furthermore, other basic test research will be conducted on hydrogen production through the reduction of iron oxide by high-temperature irradiation, as well as on radiation pyrolysis of plastics, pitch and tar.

## Nuclear Energy Developments Discussed

### Nuclear Fuel Site Development Projects Described

90CF0118 Tokyo GENSHIRYOKU SANGYO  
SHIMBUN in Japanese 14 Sep 89 p 2

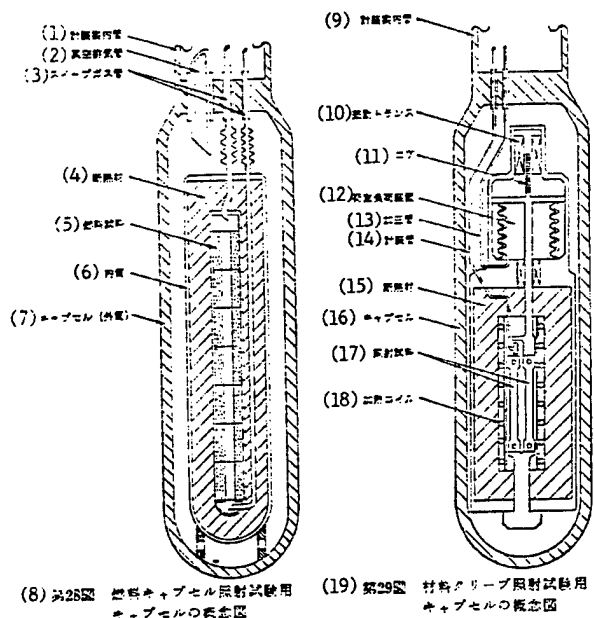
[Text]Aim for Comprehensive Promotion

### Rokkasho District Improvement Project Determined; Multipurpose Dome Construction Included

The promotion project to improve the environs around the site selected for a private reprocessing facility (reprocessing capacity: 800 tons a year), which Aomori Prefecture presents to the Ministry of International Trade and Industry [MITI], was approved on 31 August.

These projects advance regional development by use of an electric power source site promotion policy grant. The several hundred enterprises involved will require an overall ¥ 30.8 billion investment from 1989 to 1998.

The subject area includes Rokkasho-mura, where the reprocessing plant will be located, and a total of 15 nearby towns and villages. The number of projects



Key: —1. Instrumentation guide tube—2. Vacuum exhaust tube—3. Sweep gas tube—4. Adiabatic material—5. Fuel sample—6. Inner cylinder—7. Capsule (outer cylinder)—8. Figure 28. Conceptual Diagram of Capsule for Fuel Capsule Irradiation Tests—9. Instrumentation guide tube—10. Differential transformer—11. Core—12. Load charging device—13. Pressurizer—14. Instrumentation tube—15. Adiabatic material—16. Capsule—17. Irradiation sample—18. Heating coil—19. Figure 29. Conceptual Diagram of Capsule for Material Creep Irradiation Tests

reaches several hundred, and each one will be advanced individually during the project period from 1989 to 1998.

As far as the connection of these projects to quality of life base, the emphasis will be to focus on basic facilities that the residents can widely make use of and improvements of facilities, such as the public halls, libraries, and hospitals, that can be called the "face" of each of these towns and villages. Although this concept has existed for some time concerning these facilities, the problem of financial resources was a bottleneck, and the realization of most of them has been slow.

As far as the promotion of industry is concerned, the goal is to introduce superior technology in dry field farming and livestock raising, which are the main industries of the region, and to begin self-renewal with industries whose productivity is high and health is strong. Invigoration is being advanced over a wide area, including production systems, technological development, and distribution processing. Moreover, every effort is being made to dig up tourist resources.

Of the individual towns and villages, Rokkasho-mura has 29 projects. The overall cost of these enterprises is ¥12.7 billion (of which ¥11.9 million is grant aid). This contains such improvements as the municipal road project for the Osame District, as well as the water supply, a multifunctional cultural hall, a vegetable pre-refrigerator, a livestock processing facility, an artificial gathering place for fish, a multipurpose dome, and a ski area.

Higashidori-mura has four projects worth ¥1.85 billion (of which ¥1.27 billion is grant aid). The enterprises being advanced are a village gymnasium and making a tourist resource of the Shimokita region "mood," such as a hidden forest sightseeing area.

Misawa has six projects, worth ¥1.57 billion (of which ¥1.39 billion is grant aid). These include Tomani-han Tourist Village, (a historical memorial hall), which mixes grazing land and an historical cultural estate; the formation of a new commercial district and a community market for holding events; and a blood vessel photographic device for the municipal hospital.

Moreover, Aomori Prefecture itself has 11 projects, worth ¥3.05 billion (of which ¥2.7 million is grant aid). With this money, it is establishing an agricultural products processing guidance center and inspection facilities for radiation in the environment beyond Rokkasho-mura.

Incidentally, the regional promotion and improvement projects accompanying the uranium enrichment plant built in Rokkasho and the low-level radioactive waste storage center site were approved last year, and from 1988 to 1997, both will total 110 projects worth ¥5.54 billion overall (of which ¥5.5 billion is grant aid). In this way, regional promotion has already begun.

### STA Director's Comments on Development Program Reported

90CF0118 Tokyo GENSHIRYOKU SANGYO  
SHIMBUN in Japanese 21 Sep 89 p 1

[Text] Interview With STA Director-General Saito

### Making Every Effort to Promote Agreement and Move Shimokita Site Forward Positively

Science and Technology Agency Director-General Eizaburo Saito, having agreed to an interview with this newspaper, said the following on the 12th about activities to promote agreement on nuclear energy development. "Obtaining the understanding and cooperation of the nation is indispensable to smoothly advancing the development and use of nuclear energy." He advocated, "In the future I would like to develop a grassroots campaign."

The Director-General's statement for this newspaper was as follows:

1. "The nation's interest has been rising recently with regard to the development of nuclear energy, and obtaining the understanding and cooperation of the nation is indispensable to smoothly advancing the development and use of nuclear energy."

"However, the current anti-nuclear energy movement has been developing across the nation and includes both housewives and the younger generation. I regret that within that group a certain misunderstanding exists about nuclear energy. Consequently, STA is making every effort with a grassroots campaign from the perspective that a direct dialog with the people is important. For example, we are sending nuclear energy experts as lecturers to study groups. Now at the end of August, we have sent experts to study groups 68 times. I want to make clear that whenever there is a request, we will send an expert no matter where. I went to Tokai-mura on the 11th, and not only were there no opposition placards at the locale, but melons have been selling well. Going to see the actual locale might be the best thing to do."

2. "The establishment of an independent nuclear fuel cycle is extremely important in terms of advancing nuclear power over the long-term in Japan and achieving a stabilization of the energy supply."

"For this reason, as a key prerequisite to the guarantee of safety with regard to the nuclear fuel cycle enterprise presently being advanced in Rokkasho-mura in Aomori Prefecture, I want to make every effort to the utmost to work for its advancement while obtaining the understanding and cooperation of the locale. Using plutonium in a fast breeder reactor is a great step forward in our energy policy. I want to move forward by listening closely to what the local residents say."

3. "Recently, the problem of the global environment accompanying energy consumption has been viewed



close up. I think that nuclear power will play an important role in the resolution of the earth's environmental problems because it does not expel carbon dioxide or nitrogen oxide, which are basic causes of global scale environmental problems such as acid rain and the greenhouse effect."

"At the Arles Summit, which was held in July, it was agreed that nuclear energy was one important means to resolve global environmental problems. As far as our nation is concerned, we would like to positively advance the development and use of nuclear energy with the guarantee of safety as a major prerequisite. Clean energy is the point in resolving the environment question. For example, solar energy costs ¥200 to produce 1 kwh. The nation will not come to use this. From the standpoint of cost, nuclear power generation is important."

4. "As for cooperation with the developing countries in the field of the peaceful uses of nuclear energy, it is important that we advance cooperation positively in accordance with the nuclear power development level of the partner country. This year, in order to discuss the best ways to achieve cooperation with our Asian neighbors, at our own initiative, we plan to establish a forum for gathering the authorities from the various Asian nations and exchanging views. In the future, I would like to advance cooperation positively and further international contributions in the peaceful uses of nuclear energy field."

5. "With regard to high-level radioactive waste, we have decided to store the waste in vitrified glass for 30 to 50 years and finally dispose of it deep underground. At present, the Power Reactor and Nuclear Fuel Development Corporation is conducting positive research and development of this problem. Bearing in mind the results of the research and development, I want to select a candidate site for future disposal."

## Particle Accelerator Developments Described

### High Energy Physics Lab Booster Accelerator Described

90CF0177A Tokyo GENSHIRYOKU GAKKAISHI in Japanese No 31 30 Sep 89 pp 997-1003

[Article by Noboru Watanabe, High Energy Physics Laboratory]

[Text] High Energy Physics Lab's Booster Accelerator Facilities

#### 1. Introduction

About 80 percent of the output pulse of the High Energy Physics Lab's 500 MeV proton synchrotron (a booster accelerator of a 12 GeV proton synchrotron (12 GeV PS)) is being sent to facilities using boosters (various neutron, meson, and medical facilities) and is being used in a wide range of academic research crossing a number of disciplines. The intensity of the booster accelerator's

proton beam was  $6 \times 10^{11}$  protons/pulse (ppp) according to the original design value. In reality, it is being operated at about  $5 \times 10^{11}$  ppp. However, a stronger beam is being sought to accompany research progress. Moreover, stronger beam intensity is indispensable in order to be successful when subsequently competing with the large facilities being built in foreign countries.

The High Energy Physics Lab's accelerator group is making every effort to increase beam intensity, such as increasing the energy of an injector (a proton linear accelerator) from the past 20 MeV to 40 MeV and, furthermore, altering the  $H^+$  (proton) injection up to now to an  $H^-$  injection (the charge alternation method). In March 1989 this group achieved a long-sought after  $2 \times 10^{12}$  ppp (6.7  $\mu A$  at a rated operation of 20 Hz). The group further hopes to achieve great results with research in various fields using this beam.

This article introduces the current situation of the various facilities, with a focus on use.

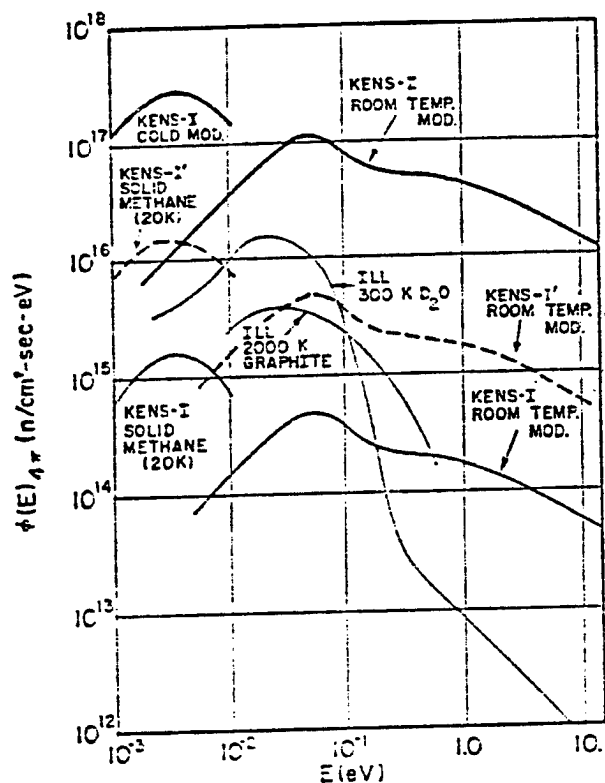
#### 2. Neutron Scattering Experimental Facility (KENS)

KENS-I is a genuine separation pulse neutron facility which takes as its main objective physics research by neutron scattering and which was the first built in the world in order, in part, to carry out nuclear and elementary particle research. It began operations in June, 1980, has a cold neutron source (20K solid methane, supports more the 200 registered joint users at present who produce about 50 scientific articles a year using 15 experimental pieces of equipment and about 1,200 hours of beam time a year.

The most important strength of the separation neutron source is that it is possible to realize a neutron source with a higher illuminance because the generation of heat per unit neutron generated is about one numerical unit less than a nuclear reactor.

It has also been called the "next generation's neutron source," and KENS-I played a role of corroborating the usefulness of a ?separation? neutron source even though it is small. The neutron generation target originally was tungsten, but in 1985, the High Energy Physics Lab succeeded in commercializing decayed uranium whose neutron capacity was twice as great (about 16 neutrons were generated per 1 500 MeV proton), and along with an increase in proton beam intensity that was subsequently carried out, the lab realized a one numerical unit increase in neutron beam intensity. We called this KENS-I'. We have even greater uses in mind, and are in the midst of working towards the realization of our future project, KENS-II (a part of the large hadron [strong particle] project. Figure VIII.1 shows the energy domain using in experiments a bundle of particle neutrons at pulse peak which can be obtained from KENS.

Figure VIII.2 illustrates the neutron laboratory equipment used in the present KENS-I'. The facility makes the most of the strengths of the pulse neutron source of each. By acting in concert with the one numerical unit increase



細線はラヴェンランジェバン研究所(ILL) (2)  
の高中性子束の値  
(1) 第Ⅷ-1図 KENSのピーク中性子束

Figure VIII.1 KENS' Peak Neutron Bundle

Key:—1. KENS's peak neutron bundle—2. The thin solid line is the value of the high neutron bundle reactor of Laue Langevan Laboratory (ILL)

in neutron beam intensity, the performance of the laboratory equipment is improved or is striving to improve, by the watchword of "one numerical unit up" when calculated in terms of beam intensity.

The most simple piece of equipment is the high resolution particle neutron diffraction device, or the HRP. It makes a hot neutron pulse of narrow width obtained from decelerating solid methane fly about 20 m and strike a test piece. By detecting scattered neutrons from the rear of the test piece, the equipment realizes a resolution of 0.3 percent, or about one numerical unit higher than in the past. Using this, the lab is actively pursuing being the first in the world to determine the crystal structure of a high heat superconductor ( $\text{BaYCu}_3\text{O}_{7-x}$ ). As for its diffraction pattern, its very many diffraction lines can be observed separately as shown in Figure VIII.3. An upgrading of performance is being planned to be able to obtain this sort of data in a short time, and it is expected to make a greater contribution to materials science. In KENS-II, high resolution of one more

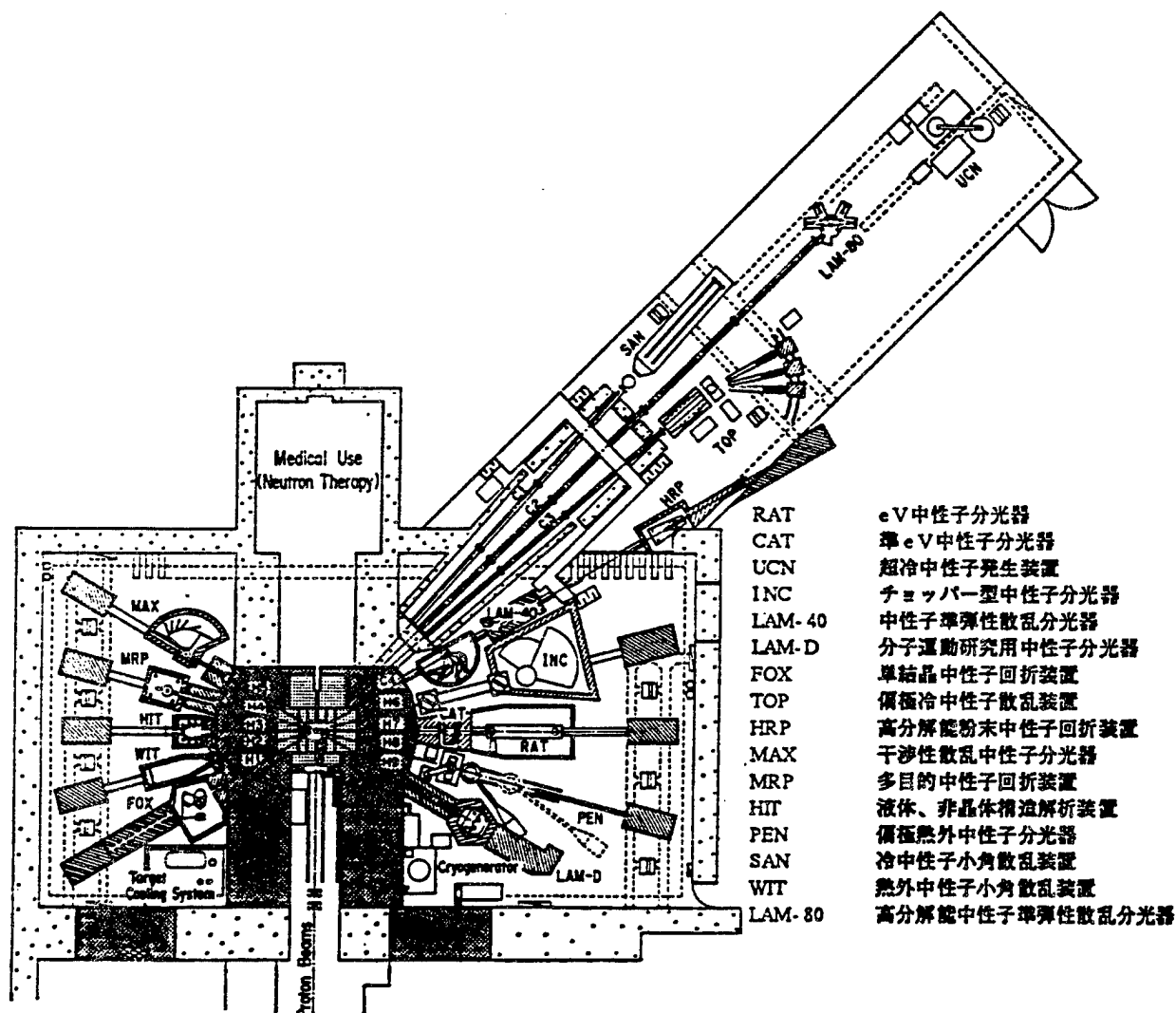
numerical unit can be obtained, and it will be possible to measure several thousand diffraction lines and to determine several hundred crystal parameters at once.

Cold neutron low angle scattering is an important means for investigating the semimacro structure of matter. In particular, in macromolecule and living matter research, a great feature is making use of the fact that the neutron scattering amplitude of heavy hydrogen and hydrogen is the reverse of plus and minus, and using the appropriate H/D substitution to investigate specific parts of matter by changing the contrast in various ways (the contrast variation method). KENS, from the time it was established, developed a device to carry out low angle scattering by using pulse-form cold neutrons. This device is known as a SAN, and is of use in research in a wide range of fields, including materials science, magnetic bodies, and living things and polymers. A major feature is that, unlike the monochromatic beam used from a nuclear reactor, the scattering over wide Q space can be observed at the same time. For example, in research on the mutual separation of the FeCr and AlZn alloy, as shown in Figure VIII.4, wide Q space data was obtained simultaneously, and it was made public, for the first time, by fitting in accordance with non-linear theory that the initial process of mutual separation could be represented by  $q^{-2}$  law.<sup>(1)</sup>

This is real-time spectroscopy of mutual separation under a specific temperature, but the time required for this measurement is still about 30 minutes to measure one scattered curved line. As for a shorter time than that, there is no other method than keeping the test piece under low heat during measurement and freezing it for a prescribed time. By means of the latest equipment development, we know that it is possible to do this sort of real-time measurement within one minute, and new equipment is being built for that. In this way, it demonstrates its power in cases where the contrast variation method is used and in experiments where high statistics are needed to subtract the contribution of solvent to great scattering, such as in the research of the structure of polymers in a solution.

Recently, a group of researchers from Gumma University carried out an important experiment on the function of living tissue by cold neutron low angle Bragg scattering using the contrast variation method.<sup>(2)</sup> Great interest is being placed in whether water permeates within the tissue, in order to explain the physiological function of the phosphatide known as triphosphoinositide (TPI), which is high in the hydrophilic property that uniquely exists in stimulated tissue. This experiment was the first to confirm that water molecules exist in the hydrophobic domain. In the past, there was the channel explanation as a tissue stimulus hypothesis, and while channel protein is believed to exist, it has not yet been discovered. However, this experiment suggests that the water molecule itself within TPI which makes up the tissue plays the role of the channel.

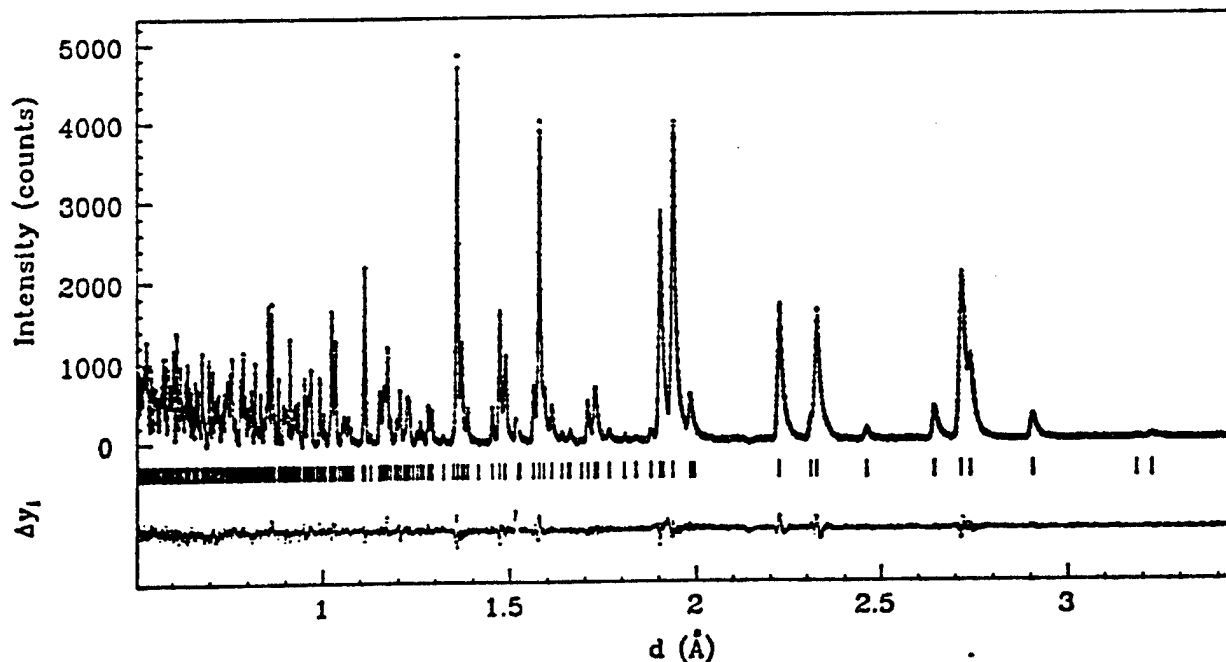
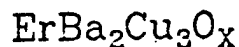
Cold neutron low angle scattering is becoming an extremely important procedure in the basic research of



第Ⅷ・2図 KENS-I'に配置されている中性子実験装置 (1)

Figure VIII.2 Neutron Experimental Devices Deployed at KENS-I'

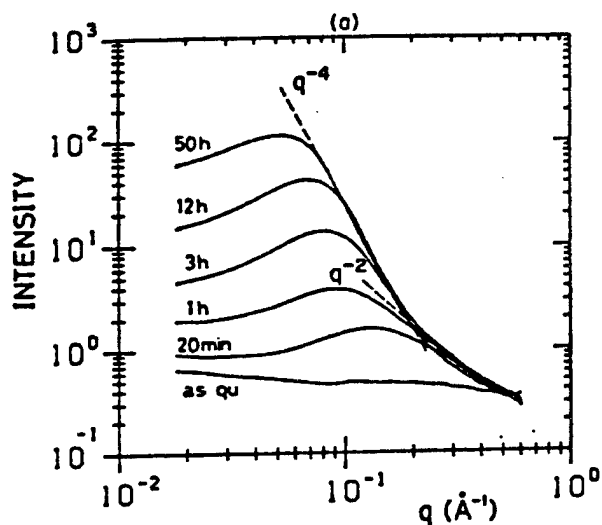
Key:—1. Neutron experimental devices deployed at KENS-I'—RAT - eV neutron spectroscopy—CAT - Quasi eV neutron spectroscopy—UCN - Supercold neutron generation device—INC - Chopper-type neutron spectroscopy—LAM-40 - Neutron quasi-elastic scattering spectroscopy—LAM-D - Neutron spectroscopy used for molecular motion research—FOX - Single crystal neutron diffractor—TOP - Polarized cold neutron scattering device—HRP - High resolution powder neutron diffractor—MAX - Interference scattering neutron spectroscopy—MRP - Multipurpose neutron diffractor—HIT - Liquid, non-crystal structural analyzer—PEN - Polarized epithermal neutron spectroscopy—SAN - Cold neutron low angle scattering device—WIT - Epithermal neutron low angle scattering device—LAM-80 - High resolution neutron quasi-elastic scattering spectroscopy



第Ⅷ・3 図 KENSの高分解能粉末中性子回折装置HRPで (1)  
測定された90K高温超伝導体の回折パターン

Figure VIII.3 Diffraction Pattern of a 90 K High Heat Superconductor Measured by the KENS High Resolution Powder Neutron Diffractor HRP

Key:—1. Diffraction pattern of a 90 K high heat superconductor measured by the KENS high resolution powder neutron diffractor HRP



第Ⅷ・4 図 FeCr合金の時効温度540℃における相  
分離の冷中性子小角散乱の実時間測定 (1)

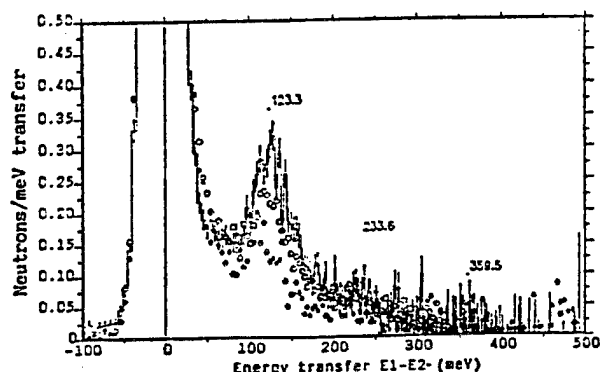
Figure VIII.4 Real-time Observation of Cold Neutron  
Low Angle Scattering of Mutual Separation in  
Prescribed High Heat of 540°C of an FeCr Alloy

Key:—1. Real-time observation of cold neutron low angle scattering of mutual separation in prescribed high heat of 540°C of an FeCr alloythe industrial community. For example, Euratom has a plan to install in ISIS, its suppression pulse neutron source facility at Great Britain's Rutherford Appleton Laboratory, equipment in which cold neutron low angle scattering can be applied to hot test pieces to undertake a special evaluation of post neutron radiation on the material of the primary wall of a fusion reactor.

One great feature of the separation pulse neutron source is that an epithermal neutron that is high in strength can be obtained as an extremely narrow pulse, and if this is used, epithermal neutron scattering, which was previously impossible, can be carried out with complete and high resolution. Recently, a chopper-type neutron spectroscopy, which is abbreviated as INC, was completed at KENS. The pulse of a chopper is matched with the burst width (about  $1.3/\sqrt{E}$  (eV)  $\mu$ s,  $E = 1$  eV at about  $1.3 \mu$ s) of the neutron is radiated from decelerating material, to that a neutron of up to 1 eV can produce a monochromatic pulse by full and high resolution. This sort of short pulse width is realized by rotating a rotor with the Soller slits of an Al metal alloy thin plate that contains  $B_4C$  insulated tungsten thin wire at a speed of 600 rotations per second by using a bearing floating on a magnet.

The scattered neutrons are detected by  $170 \text{ } ^3\text{He}$  proportional tubes deployed around the test piece and converging on the front, and energy analysis is made by means of the time of flight method. Figure VIII.5 observes the high energy magnetic stimulus by the crystal field division of the metal samarium (Sm), and the incidental neutron energy is 600 MeV.<sup>(2)</sup> There is a need to measure by the changing  $Q$  of the low quantity of motion because of the magnetic form factor, and because of the kinematic constraints of a neutron, this sort of high energy incidental neutron can be tested for the first time by obtaining high resolution ( $< 1$  percent) and full strength.

The understanding of high heat superconductor mechanisms is one of the most important tasks today, and great interest is gathered in the question of how much high



ピークの上を示す数字は励起エネルギー (meV)。スペクトルは上より  $Q=2.8, 3.6, 5.9 \text{ } \text{\AA}^{-1}$  の測定値 (2)

第Ⅷ-5図 KENSのINCで測られたSmの高エネルギー磁気励起 (1)

Figure VIII.5 High Energy Magnetic Stimulus of Sm as Measured by KENS' INC

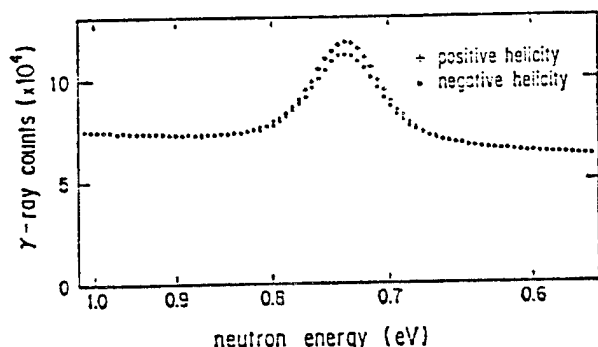
Key:—1. High energy magnetic stimulus of Sm as measured by KENS' INC—2. The numbers shown above peak are stimulus energy (MeV). The spectrum is the measure value of  $Q = 2.8, 3.6, 5.9 \text{ } \text{\AA}^{-1}$  more than the above.

energy exists in the spin frequency inside the superconductor. INC is also challenging this. This device is indispensable for the measurement of the scattered function of liquid bodies and non-crystalline bodies  $S(Q, \omega)$ , and future results are anticipated.

As a final example, I would like to introduce PEN, the polarized epithermal neutrons spectroscopy, which only exists at KENS in the whole world. The polarization of a neutron is the complete reflection of a magnetic mirror by a cold neutron. Moreover, it is carried out relatively easily in a thermal neutron by a strong magnetic crystal structure. However, it is not carried out easily in a neutron without heat. KENS succeeded in using a proton filter polarized by a dynamic polarization method as a polarized epithermal neutron particle. KENS is using this in experiments related to the destruction of the symmetrical nature of the nucleus of an atom and in experiments of physical properties. The polarized particle is ethylene glycol doped with several percent of Cr mixture with a value of 5. The protons inside that are frozen to less than 0.5 K by liquid  $^3\text{He}$  pumping and are polarized by 70 GHz microwave pumping with a 2.5 T magnetic field. A polarization degree of about 80 percent is presently realized, but if a filter made up of 5 polarized particles is used, a polarization degree of 70 percent can be achieved for neutrons above 1 eV, and a polarization degree of above 90 percent can be achieved for thermal neutrons. Research is proceeding into the parity non-conservation (PNC) of the nucleus of an atom by using a beam of this sort of polarized neutron without heat. The effect of an extremely large PNC was initially confirmed as 9.4 percent by the resonance existing in 0.734 eV of  $^{139}\text{La}$ .<sup>(3)</sup>

Figure VIII.6 is a study of the energy dependence of a neutron with a captured  $\gamma$  ray strength by applying the helicity of incidental neutrons to test pieces that are parallel or unparallel in the direction in which they are proceeding. The PNC effect is confirmed from the gap between the two. In experiments up to this which use cold neutrons, this value is extremely small at  $10^{-3}$  to  $10^{-4}$ . This is calling attention to the development of a new theory on why this sort of large PNC effect can only be observed in the specific resonance of certain kinds of atomic nuclei. This sort of experiment is trying to develop into further ambitious experiments on the break up of time reversal, which is an important theme from the standpoint of basic physics.

There are many other devices besides these. All sorts of interesting research is being undertaken, and this is briefly described on the pages of this journal. As a result, the separation pulse neutron source is extremely useful in the science of matter by means of neutron scattering and in certain fields of research into the nucleus of an atom. By realizing the improved performance of the experimental equipment being considered for the future



第Ⅷ-6図 KENSの偏極熱外中性子分光器PENを用いて観測された標的核 $^{139}\text{La}$ の0.734 eVの共鳴でのパリティ非保存の実験結果 (1)

Figure VIII.6 Results of the Experiment on the Non-preservation of Parity of Resonance of 0.734 eV of the Target Nucleus  $^{139}\text{La}$  Which was Observed by Using KENS' Polarized Neutron Without Heat Spectroscopy PEN

Key:—1. Results of the experiment of the non-preservation of parity of resonance of 0.734 eV of the target nucleus  $^{139}\text{La}$  which was observed by using KENS' polarized neutron without heat spectroscopy PEN

and the increase in beam strength of a surging accelerator, I believe that great uses are being found that will make a contribution to the developed of base technology in the industrial community.

Tokyo University Meson Science Laboratory Center (UT-MSL)

This center was established in 1978 as a meson science facility of the Science Department of Tokyo University, with the aim of generating a pulse form muon by using a 500 MeV proton obtained from a booster synchrotron and using this to carry out interdisciplinary research in solid state physics and nuclear physics, and chemistry. It has explored all the new types of basic physics and applied science fields up to today since it began experiments virtually simultaneously with the neutron. In 1988, it reopened as the Tokyo University Meson Science Laboratory Center, and is attempting to achieve a second period of development.

Position and negative pi mesons ( $\pi^+$ ,  $\pi^-$ , called pions) have been obtained by nuclear reactions when a proton of more than 300 MeV struck a light nucleus of Be. The pion will decay at an average life of 0.026  $\mu\text{s}$  in stationary time, and becomes a positive or negative  $\mu$  particle ( $\mu^+$ ,  $\mu^-$ , known as a muon). The real quantity of a muon is 207 times an electron and has half the spin. It is obtained by 100 percent polarization.  $\mu^+$  and  $\mu^-$  decay with an average life of 2.2.  $\mu\text{s}$  and become neutrinos and protoelectrons or electrons.

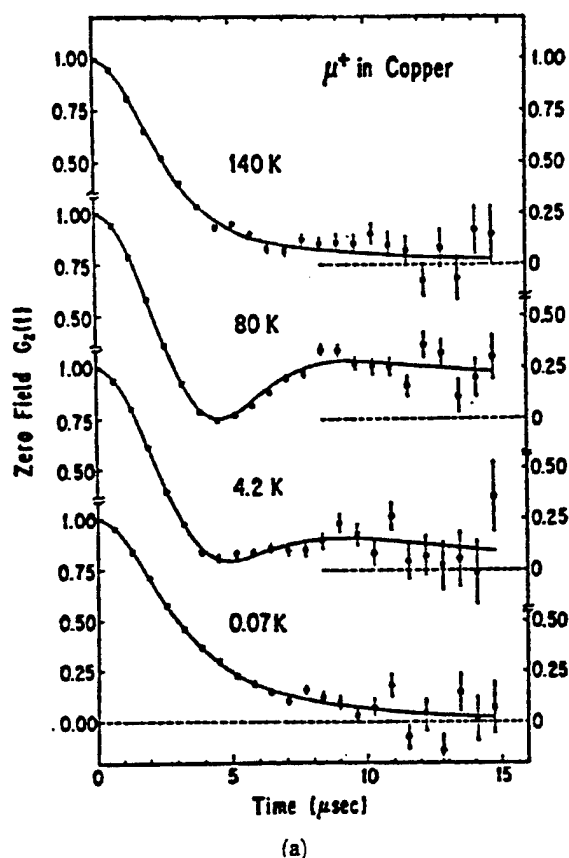
Well then, the  $\mu^+$  which is fired into the matter decelerates to less than 1 ns and heats up and stops at a positions

within the lattice of the matter, or scatters among these. It unites with the electrons inside the matter at that time and creates muonium in the form of small hydrogen atoms. On the other hand,  $\mu^-$  is bound like an electron to the nucleus and forms the shape of a muon atom. Observing the magnetic field that the muon experiences in the matter and its fluctuation in the  $\mu\text{SR}$  method.<sup>(4)</sup> There are three processes in this: the rotating process, the easing process, and the resonance process.  $\mu^+$  maintains 100 percent polarization when halted in positions within the lattice. Proto-electrons or electrons radiated when a polarized muon decays after its average life, goes out along the direction of the muon's spin, and by means of measuring these protoelectrons and electrons with counter-telescopes, we can investigate the direction and fluctuation of the muon spin.

We will introduce here research on quantum scattering under the low heat of  $\mu^+$  within metals as a representative example of an experiment undertaken by the easing method. Figure VIII.7 (a) observes, under all sorts of temperatures, the manner in which the degree of polarization of the  $\mu^+$  spin in the pure Cu test piece changes over time; in other words, the easing function. By analyzing this data, the hopping rate of  $\mu^+$  and the size of the disturbance of the magnetic field made in a random direction of the moment of a Cu nucleus around the  $\mu^+$  position. Figure VIII.7 (b) indicates the changing of the temperature of the  $\mu^+$  hopping rate. It was first discovered that under 40 K, the value increases as the temperature decreases. Above 40 K, this can be explained by a quantum scattering model aided by many phonons, but with less than 40 K, Kondo<sup>(7)</sup> explained this splendidly by developing a theory incorporating the mutual interaction of  $\mu^+$  and conducted electrons (real line).

Whereas  $\mu^+$  is the key player in the  $\mu\text{SR}$  experiment, the large possibility of  $\mu^-$  use is muon nuclear fusion ( $\mu\text{CF}$ ). If  $\mu^-$  is entered into a  $\text{D}_2/\text{T}_2$  mixture, muon atoms such as neutral ( $\mu\text{d}$ ) and ( $\mu\text{t}$ ) emerge and, reacting in resonance with the surrounding  $\text{D}_2$  and  $\text{DT}$ , a meson particle of about  $5 \times 10^{-11}$  radius, in which  $\mu^-$  goes around the circumference of a nucleus of  $\text{d}+\text{t}$  appears. When  $\text{d}$  and  $\text{t}$  are close in this manner, a nuclear fusion reaction occurs, and  $\alpha$  and a meson are generated, but in  $\mu^-$  of a large portion, a nuclear fusion reaction creating new muons is repeated again and again (muon medium nuclear fusion).<sup>(8)</sup>

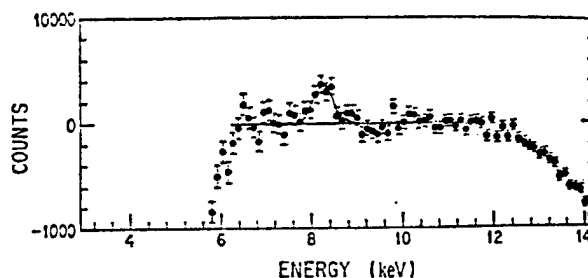
There is great interest in the fact that one  $\mu^-$  contributes to the creation of numerous nuclear fusions because this is the decisive evidence in the question of whether  $\mu\text{CF}$  can be established as a means of energy production. Thus, its upper limit is determined, but  $\mu^-$  is considered to be attached to  $\alpha$ . The probability that it will be captured in  $\alpha$  is small, and to accurately seek this from observations of neutrons generated by nuclear fusion is extremely difficult. Therefore, it is important to directly observe X-rays of muon atoms which generate when  $\mu^-$  is captured in  $\alpha$ . However, experiments of enriched commercialized  $\text{D}_2$  and mixtures by hindering the damping



第Ⅷ-7図 (a), (b) Cu 中の  $\mu^+$  のゼロ磁場緩和関数の時間スペクトルの温度変化(a), ホッピング率の温度変化(b)

Figure VIII.7 (a) Time Spectrum Temperature Changes (a) and Hopping Rate Temperature Changes (b) of the Easing Function of a Zero Magnetic Field of  $\mu^+$  Inside Cu

Key:—1. Time spectrum temperature changes (a) and hopping rate temperature changes (b) of the easing function of a zero magnetic field of  $\mu^+$  inside Cu—2. Real line is the value by the Kondo theory radiation of  $\beta$  rays which are radiated from T, were impossible even in the powerful meson factories of other countries.



第Ⅷ-8図  $\mu^-$  が  $\alpha$  に捕獲された時に発生する特性X線(8.2 keV のところにピーク)の実測データ

Key:—1. Real measured data of X-rays characteristically generated when  $\mu^-$  is captured in  $\alpha$  (peak when at 8.2 keV)

Figure VIII.8 Real Measured Data of X-Rays Characteristically Generated When  $\mu^-$  is Captured in  $\alpha$  (Peak When at 8.2 keV)

On the other hand, as for the strength of the UT-MSL muon beam, the average value is not large, but the instant value of the pulse surpasses other by more than  $10^4$  times. Therefore, we can observe X-rays by overcoming the aforementioned damping radiation background. Figure VIII.8 is the result of a recently conducted experiment and succeeds in observing X-rays accompanying  $\alpha$ 's capture of  $\mu^-$ .<sup>(2)</sup> The analysis of data to determine the probability that  $\mu^-$  will be attached to  $\alpha$  is presently being conducted.

Next we will introduce a superslow speed  $\mu^+$  experimental facility presently under construction at UT-MSL. The UT-MSL group has succeeded, by carrying out joint research with AT&T's Bell Laboratories, in creating thermal energy (several 10 to several 100 MeV) muonium inside a vacuum. A monochromatic  $\mu^+$  beam of several keV can be obtained by dissociating this into  $\mu^+$  and electrons by hitting it with a strong laser light of 244 nm, and transporting this  $\mu^+$  up to the position of a measuring instrument in a binding and accelerating electric field of several keV. This beam is expected to open research of basic atomic physics and all sorts of new interdisciplinary research, such as the question of the speed of chemical reactions of muonium and other atoms and molecules, and the surface properties of the primary atomic layer of solid surfaces.

## 4. Particle Ray Medical Science Center (PARMS)

PARMS is a facility at Tsukuba University, which was established with the objective of opening paths for the treatment and diagnosis of cancer by using protons from the booster synchrotron. Proton ray treatment has been carried out on 129 patients from 1982 to the end of March, 1989. As shown in Table VIII.1, success was achieved as a result of treatment in 94 cases that were completely cured, including deep internal cancer.<sup>(2)</sup> The following are the three main reasons for achieving this high local cure rate.

(1) The protons, when irradiated into the human body, as shown in Figure VIII.9, provided a high amount of radiation several times more than the skin surface at the point where the range ended.<sup>(9)</sup> By adjusting the energy

of the proton beam and unifying a high portion of this radiation amount with the focus of the infected area, we can selectively destroy only the tumor area without injuring the normal cell organization to that extent. This is largely different from the traditional radiation treatments with X-rays and neutron rays.

(2) Prior to irradiation, a best radiation treatment plan is established by using a computer by means of a multilayered X-ray CT video, including the focal area of the cancer. Ordinarily, radiation is carried out from two openings on the front and side, and a supplemental filter is created to match the shape of the focus of the infection on each irradiated surface.

(3) Vertical radiation which is not in the proton ray treatments of foreign countries is possible at this facility. This fact may not be considered to be important at first glance, but it is linked to the high success of treatment since it can fix patients during radiation.

To draw conclusions about the success of proton ray treatments in comparison with other methods, we would need to go over the more than 300 medical cases, but the success rate of proton rays is already high, and Tsukuba University has built a proton accelerator for the exclusive use of the neighboring university hospital. Proton ray treatment has begun there in earnest.

(3)	(1) (1989年3月末現在)		(2) 症 例 数	
	6ヶ月以上 前治療終了	推定局治	後遺症	(6)
(7) 皮膚	5	5		
(8) 舌	3	3		
(9) 頬粘膜	1	1		
(10) 中耳	1	1		
(11) 耳下腺	2	2		
(12) 肺	12	9		
(13) 食道	11	10	1	
(14) 胃	3	2		
(15) 肝	7	7		
(16) 直腸	1	1	1	
(17) 子宮	16	15		
(18) 陰嚢	2	2		
(19) 腎	4	1		
(20) 膀胱	6	1	3	
(21) 前立腺	5	4	1	
(22) 後腹膜	1	1		
(23) 小計	80	65(81%)	6(7.5%)	
(24) 脳	14	5	5	
(25) 計	94	70(74%)	11(11.7%)	

Table VIII.1 Proton Ray Treatment Results  
(Treatments with the Objective of Total Cure) (At  
Present the End of March of 1989)

Key:—1. Proton ray treatment results (Treatments with the objective of total cure) (At present the end of March of 1989)—2. Number of cases—3. Internal organ—4. Treatment ends before more than six months—5. Estimated local treatment—6. Aftereffect of a disease—7. Skin—8. Tongue—9. Cheek mucuous membrane—10. Middle ear—11. Parotid gland—12. Lungs—13. Alimentary canal—14. Stomach—15. Liver—16. Rectum—17. Womb—18. Vagina—19. Kidneys—20. Urinary bladder—21. Prostate gland—22. Afterbirth membrane—23. Subtotal—24. Brain—25. Total

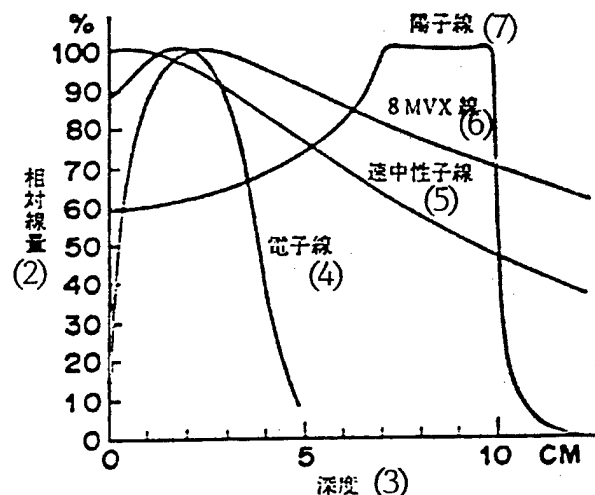


Figure VIII.9 Comparison of the distribution of doses of radioactivity with the depth of the body of various kinds of radiation

Key:—1. Comparison of the distribution of doses of radioactivity with the depth of the body of various kinds of radiation—2. Comparative dose of radioactivity—3. Depth—4. Electron rays—5. Fast neutron rays—6. 8 MV X-rays—7. Proton rays



(Received July 19, 1989)

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**JAERI's Ion Beam Irradiation Accelerator  
Described**

90CF0177B Tokyo GENSHIRYOKU GAKKAISHI in  
Japanese No 31, 30 Sep 89 pp 983-986

[Article by Miuki Hagiwara and Ryuichi Tanaka of the  
Japan Atomic Energy Research Institute [JAERI]]

[Text] JAERI's Ion Beam Irradiation Accelerator

JAERI's Kozaki Laboratory is moving ahead with the construction and preparation of the present accelerator facility in order to proceed with research into the uses of ion beam irradiation, in addition to research using  $\gamma$  rays and electron-rays, which has been going on up to now. This article provides a summary of the research and facilities plan and describes the current state of preparation of the facility.

1. Research Contents

When ion beams extend the functions of electrolytic dissociation (ionization) and stimulus to matter, they are basically no different than  $\gamma$  rays and electron rays. However, when ion beams move energy, they possess the notable feature of moving atoms and molecules which have a large quantity of motion. Consequently, with ion beam radiation, not only do we have local and high precision ionization and stimulation, we can use the effect of irradiation that is its special feature by the expulsion of atoms and nuclear reactions. Moreover, when we make use of its superior control as a charged particle and its special feature of the movement of atoms and molecules, we have an effective means for materials processing and new substance creation. Making use of this sort of special feature, the JAERI research using ion beam irradiation is being conducted as follows.

Space development and nuclear fusion reactor development takes among their objectives the development of radiation resistant materials and the establishment of materials that can pass environmental assessments. In the research and development of space environment materials, the higher functioning of man-made satellites and the improved performance of longer life spans are considered to be important. Hence, research and development is being conducted with regard to the technologies needed for an understanding of the deterioration mechanism caused by space rays on semiconductor chips, an elevation of technology to assess radiation resistance, and an improvement of radiation resistance.

In the research and development of nuclear fusion reactor materials, ion beam radiation is being used as a means of imitating the deterioration function of high energy neutrons in a nuclear fusion reactor environment. This is contributing to the effective advancement of the development of such materials as organic composite materials used in superconductor magnetic insulation materials, metal and inorganic materials such as blanket material, and structural materials for plasma vessels.

Moreover, in the field of biotechnology, ion beam radiation is advancing the development of technology to process by radiation minute units within cells, since ion beams contain superior control features. It is also advancing the manufacturing of new genetic resources which make use of the characteristic of a high sudden transformation rate. In addition, it is advancing the development of new signal chemical compound synthesis methods and the manufacture of short-life RI in medical research, by making the most of the special features of a large-scale AVF [azimuthally varying field] cyclotron mentioned below. By these activities, it is contributing to progress in the life science field, such as the production of useful substances by microbes, the elevation of breeding technology of environment resistant crops, and the explanation of the functions of living organisms.

As for research of function materials, such as the creation of new substances, research is being conducted on control technology for composition and structure by advancing research of the elemental process of material formation by combining ion striking with analytic technology. This creation of materials with new composition and structure by ion striking is the first such use of ion beam irradiation in this area. Furthermore, ion beam irradiation is contributing to the progress of new materials development by integrating the results of the functional assessments of the materials obtained and proceeding with the building of a knowledge base for materials design and processing technology.

As in the above, the plan of JAERI's Kozaki Laboratory is to attempt to proceed comprehensively with research using ion beam irradiation for biotechnology. The laboratory aims to advance this effectively by cooperation with private industry, university, and government researchers. Already it has obtained the participation of

over 100 researchers from outside of JAERI. Nineteen research groups have been formed, and pioneering research activity is moving forward.

## 2. The Accelerator Facility and the Characteristics of Beam Use

The accelerator facility is being planned with the objective of making the contents of the research plans stated above fulfilled as much as possible. Based on the reliability of accelerator operation as viewed from the standpoint of the required ion type, acceleration energy range, electric current range, beam use modality, and radiation use, the type and capacity of the accelerators has been determined.

In particular, with regard to the range of energy, a wide range of energy is covered from the less than MeV territory, which has recently begun to be used well in research in the materials field to several hundred MeV which has not been used too much up to now. Moreover, the use of a wide variety of ions is included, and the installation of a number of accelerators with different acceleration energy ranges is necessary.

As far as high energy use is concerned, a large-scale AVF cyclotron equipped with an ECR (electron cyclotron resonance) ion source was chosen. It was selected because the acceleration of a wide variety of ions would be possible, a large electric current of light ions would be obtainable, and, moreover, it has a high reliability of operation with a basically already proven track record as a device using radiation. As far as the use of low and medium energy is concerned, three accelerators were chosen. These were a 3 MV tandem accelerator, a 3 MV single end-type Vandegraph accelerator, and a 400 kV ion injection device. This is because these forms of energy can be achieved by basically making possible the use of an integrated beam that radiates simultaneously the beams of two or three accelerators in a single port. The basic output capacity of the four accelerators is shown in Table IV.1.

The AVF cyclotron has been used up to now mainly for nuclear physics research and medical uses. However, recently, tests have been widening for use in materials science and life science research by high energy ion beaming. However, the plan to build a large-scale AVF cyclotron with these types of research as the main goal is the first such attempt in the world. Along with large improvements in operational capacity, output, and the wide variety of ions that can be accelerated by the rapid development of ECR ion source technology, the fact that the cyclotron is becoming a tool with wider uses is also a factor for furthering applications in new fields outside the research area already demanded.

JAERI's cyclotron is the 930 model produced by Sumitomo Heavy Industries which already has a performance record at the National Institute of Radiological Sciences. However, this one will have many added improvements, such as making the ion source from an externally established method rather than an internally established

method, changing the method of an RF-type resonator to a maximum voltage 60 kV moving-shot type resonator for the purpose of easily extracting proton beams of a 90 MeV maximum energy, and making use of computer control methods. Moreover, in order to make possible acceleration of many types of particles over a wide range of energy, a core region was devised to make operations in the harmonic modes 1, 2, and 3 possible. The maximum acceleration energy of heavy ions will depend on the capacity of multivalue ion creation by the ECR ion source, but in the "octopus" of Louvanne University, which is installed in this equipment, acceleration above 600 MeV can be obtained in Ar.

The cyclotron and tandem accelerator is scheduled to be completed in 1991, including a beam course using 10 cyclotrons, and the entire research facility is scheduled to be completed in 1993.

Many new features are being demanded of ion beam technology in order to meet a wide range of research projects. Table IV.2 shows the main beam use features planned for this research facility. Since uniform radiation of a wide area does not take as a subject irradiated objects of complex forms as in cancer treatment radiation, elaborate technology is not particularly needed. However, since a large electric current is required in material radiation, a means for confirming uniform radiation, postradiation radioactivation, the freezing of test pieces, and the handling of residue beams remain as technological tasks. The beam from the cyclotron is pulse-shaped, of course, but along with making the time interval between pulses variable over a wider range by thinning out, making the pulse-width as short as possible is also being sought.

Since, in an AVF cyclotron, a great number of pulses are produced ordinarily to respond to the emission of the single beam pulses combined with accelerating frequencies, this project is designed so that a single pulse is produced by installing a beam chopper in the entrance and exit of each cyclotron. An ion microbeam in the MeV range had been used in beam analysis by light ion beams up to now, but in this facility, the plan is to apply it over wide fields of research, including cellular processing technology and single event effects caused by heavy ions. In heavy ions, a permeable high energy ion is necessary, and microbeam equipment with these features is scheduled for installation in the three accelerators. The goal is to have a beam size of 1  $\mu\text{m}$  or less.

The use of an integrated beam using multiple accelerators will be used in research imitating the effects of radiation on materials and research of beam analysis technology. A combination of three different accelerators is planned for the latter, and the attempt to be able to deal with a wide range of subjects for analysis overall is a special feature.

(Received July 20, 1989)

**Table IV.1**  
**Major Characteristics of Riken's Ion Beam Radiation Accelerator**

Accelerator	Accelerated Particle	Accelerated Energy (MeV)	Maximum Electric Current ( $\mu$ A)	Characteristics of Beam Use
AVF cyclotron	Proton	5-90	30	Heavy ion generation (ECR ion source)
	Heavy proton	5-53	40	Uniform radiation over a large surface
	He	10-100	20	Pulse beam
	C	30-330	5	Neutron beam generation
	Ne	50-550	5	Microbeam
	Ar	100-700	5	Integrated beam use
	Kr	200-630	1	Secondary proton beam generation
Tandem-type accelerator (3 MV)	Xe	310-620	0.1	
	Proton	0.8-6.0	5	Microbeam
	C	0.8-15.0	10	Integrated beam use
	Ni	0.8-15.0	5	
	Au	0.8-9.0	15	
Vandegraph (3 MV)	Proton	0.4-3.0	300	Microbeam
	Heavy Proton	0.4-3.0	200	Integrated beam use
	He	0.4-3.0	200	Electron beam generation
	Electron	0.4-3.0	100	
Ion injector (0.4 MV)	He	0.025-0.4	50	Multitype ion generation
	Ni	0.025-0.4	30	Integrated beam use
	Au	0.025-0.4	30	

**Table IV.**  
**2 Beams Use Characteristics in JAERI's Ion Beam Irradiation Accelerators**

Beam Use Method	Accelerator	Particle	Energy Range	Beam Characteristic	Research Use Fields
Uniform radiation of a wide radiation field	C	p	5-50 MeV	Radiation field less than or equal to 100x100 mm (electric current)	Semiconductor and organic materials, radiation deterioration of electric parts, inducement of sudden plant mutations
		HI	Greater than or equal to 300 MeV	Radiation field less than or equal to 50x50 mm	
Pulse beam	C	All accelerated particles	Virtually the whole accelerator range	Pulse wide less than or equal to 2-3 ns	Radioactive chemical reactions, microdosimetry, ion beam analysis, nuclear data preparation
				Pulse interval: 1 $\mu$ s-1 ms	
Secondary neutron beam		D( $\rightarrow$ Be)	10-50 MeV	Fluence less than or equal to $10^{17}$ cm <sup>-2</sup>	Radiation deterioration of materials and electric parts
	C			Radiation field less than or equal to 20x20 mm	Neutron radiography
		p( $\rightarrow$ Li)	20-90 MeV	Monochromatic high acceleration neutron beam	Neutron cover basic data preparation
Microbeam	T	Ni, Si, C, He	3-15 MeV	Minimum beam diameter: 1 $\mu$ m	Single event effect of semiconductor chips, etc.
				Minimum fluence rate, single ion hit	

**Table IV. (Continued)**  
**2 Beams Use Characteristics in JAERI's Ion Beam Irradiation Accelerators**

Beam Use Method	Accelerator	Particle	Energy Range	Beam Characteristic	Research Use Fields
Uniform radiation of a wide radiation field	C	p	5-50 MeV	Radiation field less than or equal to 100x100 mm (electric current)	Semiconductor and organic materials, radiation deterioration of electric parts, inducement of sudden plant mutations
	V	p, d, He	1-3 MeV	Minimum beam diameter < 1 $\mu$ m	Ion beam analysis
				High electric current density	
	C	HI, He	Virtually the whole accelerator range	Minimum beam diameter: ~ 1 $\mu$ m	Cell processing technology, microdosimetry
				Extremely minute fluence rate, single ion hit	Single event effect of semiconductor chips
Integrated beam use	T+V+I	HI+p+He	less than or equal to several MeV	Simultaneous triple beam radiation	Nuclear fusion materials research
	V+I	LI+He	less than or equal to 3 MeV	Dual beam (I: strike, V: analysis)	Ion beam analysis technology (in-situ)
	T+I	LI+He	less than or equal to several MeV	Dual beam (I: strike, T: analysis)	Ion beam analysis technology (in-situ)
	C+T	HI+He	less than or equal to 100 MeV(C)	Dual beam (T: strike, C: analysis)	Ion beam analysis technology (in-situ)
Vertical beam	C	HI, He	Virtually the whole accelerator range	Uniform radiation in air, wide radiation field	Radioactive chemistry, radioactive biology, microdosimetry, etc.
Secondary proton beam	C	p, d, He	5-50 MeV	Low speed monochromatic proton beam	Electron structural analysis of materials (proton destruction method)

C: AVF cyclotron, T: 3 MV tandem accelerator, V: 3 MV Vandegraph, I: 400 kV ion injector, LI: Light ion, HI: heavy ion

**Riken's Accelerator Research Facility Described**  
90CF0177C Tokyo GENSHIRYOKU GAKKAISHI in  
Japanese No 31, 30 Sep 89 pp 986-989

[Article by Hiromichi Uetsubo, Institute of Physical and Chemical Science [Riken]]

**Riken's Accelerator Research Facility**

**1. Introduction**

Riken's ring cyclotron project has already been reported in this journal.<sup>(1)</sup> However, at that time, immediately after the ring cyclotron itself was completed, construction began of an AVF cyclotron, which is a measurement device and a second radiation injector. The report focussed on a description of the ring cyclotron itself. In March of 1989, the entire construction project was finished and a large portion of the measurement device originally planned is also finished. Therefore, at this time, I will introduce Riken's accelerator research facility while emphasizing the equipment recently built.

The Riken ring cyclotron (RRC, completed in 1986) is the central device of the "Heavy Ion Science Accelerator Facility" project, which began construction in 1974. This facility has a heavy ion ray-type acceleration (RILAC, completed in 1980) and an AVF cyclotron (AVF, completed in 1989) as

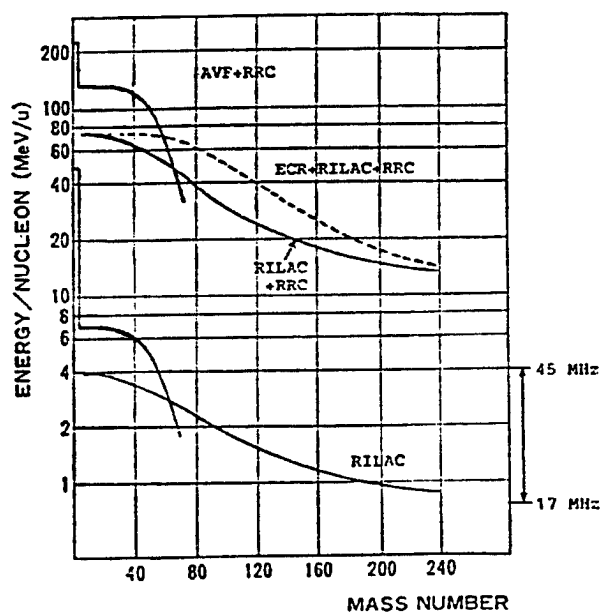
first-stage accelerators, and this is an integrated accelerator system with the RRC as the latter-stage accelerator. This facility can accelerate ions from over a wide range from protons and heavy protons up to U at high energy, and is a high performance facility found nowhere else in the world. Figure V.1 shows the highest energy achieved when various ions are accelerated by RILAC, AVF, and RRC. In the graph, the horizontal axis represents the mass number of ions, and the vertical axis represents the accelerated energy as the energy per nucleon.

Recently, Riken injected a nitrogen ion ( $^{14}\text{N}$ ) from the AVF to the RRC and achieved energy of 135 MeV per nucleon, and as far as a continuous beam is concerned, it succeeded in accelerating up to the highest energy level in the world in this case.

**2. Summary of the Accelerator Facility**

Figure V.2 shows a plane deployment diagram of the entire facility in order to grasp the entire picture of the heavy ion accelerator facility.

RILAC use a 500 kV Cockcroft-type accelerator (I in the diagram) as an injector. Multivalued ions emerging from an ion source installed on top of a direct current, high voltage terminal are first accelerated at 500 kV and then accelerated by RILAC. RILAC's maximum acceleration energy is



第V・1図 理研リングサイクロトロン重イオン  
(1) ビームの最高エネルギー

Figure V.1 Maximum Energy of Riken's Ring Cyclotron Heavy Ion Beam

Key:—1. Maximum energy of Riken's Ring Cyclotron heavy ion beam ( $16qx$ ) MeV, when  $q$  is the charge of the ions. At present a PIG-type device is the ion source, but an ECR ion source is scheduled to be introduced shortly. Since the ECR ion source generates stably heavy ions with a high  $q$ , its introduction is expected to increase the acceleration energy of RILAC (the dotted line in Figure V.1) and allow for more stable operation. RILAC is used as an injector when RRC is accelerating ions heavier than Ar, but besides that, it is operated by itself and is used for its own experiments, such as atomic collisions. At present a variety of measuring devices have been installed in its six beam lines.

The AVF cyclotron is an injector used when relatively light ions are accelerated into high energy. The  $K$  value is 70 MeV, so if ions with a mass number of  $A$  and a charge of  $q$  are accelerated, its maximum energy will be  $70x(q^2/A)$  MeV. This cyclotron has the first outside ion source in Japan, and the ions are injected from a vertical direction into the core of the cyclotron. The external ion source is installed in a room right above the AVF room. At present,

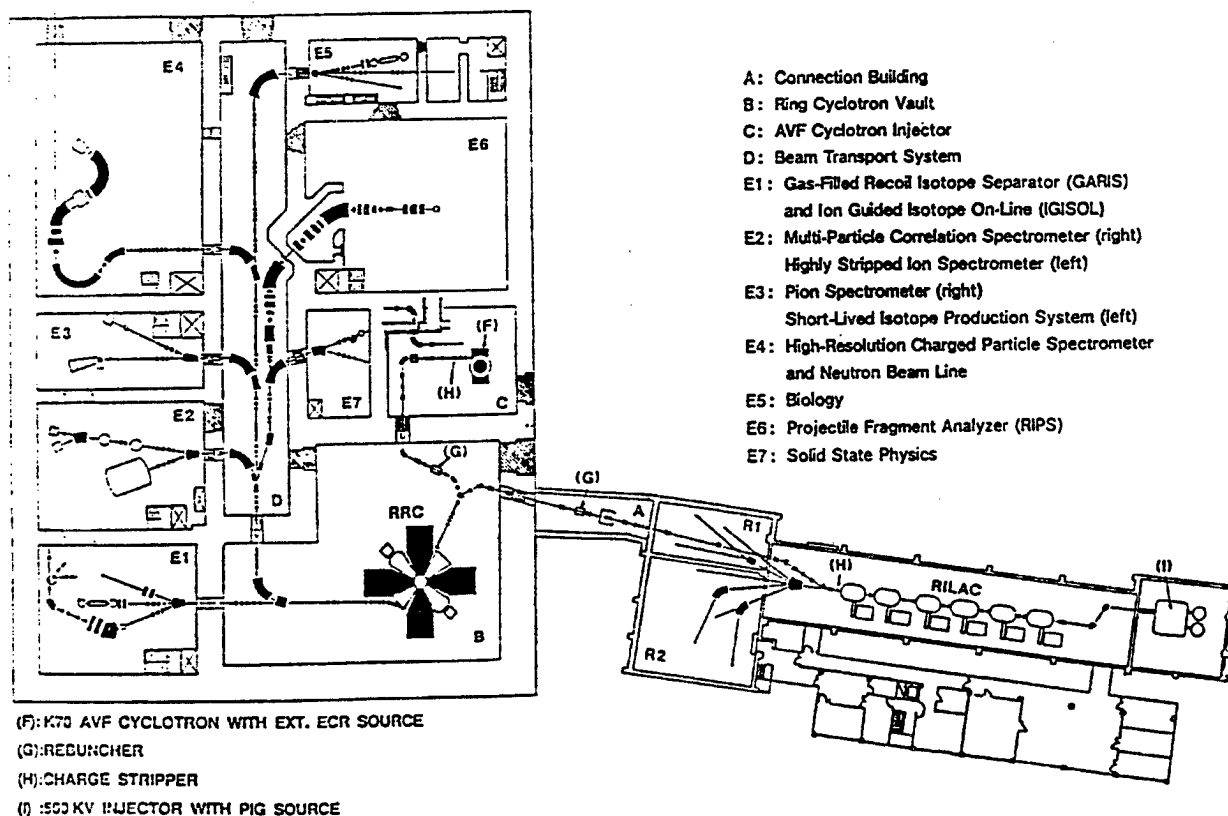


Figure V.2 Riken's Accelerator Research Facilities

Key:—1. Riken's accelerator research facilities

an ECR-type ion source for heavy ions and a duoplasmatron for protons are operating in that room. A polarized ion source is scheduled to be built there in the future.

Riken developed the ECR ion source used by the AVF. The strength of its multivalued ions is extremely great, and it is in the highest class of ion sources in the world. When the AVF is not operating, it is used in low energy atomic collision experiments. When AVF is not being used as an injector for RRC, it is operated independently and is provided for experiments. As a result, two beam lines have been installed.

RRC is a separation sector-type cyclotron consisting of four fan-shaped electromagnets. Its K value is 540 MeV. When it receives an injection from LIRAC [sic, should be RILAC], its harmonic number equals 9. When it receives an injection from AVF, it accelerates to  $h=5$ . Its maximum energy at that time is shown in Figure V.1. However, according to the experiment, heavy ions of considerably low energy are required. Consequently, it has succeeded in attempts at acceleration of greater than  $h=9$  when receiving injections from RILAC. Heavy ion acceleration up to a low energy of 10 MeV per nucleon has been possible up to now. No other accelerator exists with so wide an accelerated energy range.

The beam from RRC has an energy resolution of less than 0.1 percent. Its emittance is measured at about 10 mm.mrad, and its bunch width is 300 ps. These values are the smallest values known in an existing cyclotron. Hence, the RRC can be said to possess the world's highest capacity.

### 3. Research Projects of the Accelerator Facility

We will introduce you below to the experimental facilities of the ring cyclotron and briefly introduce you to its research projects. Consequently, we will explain the radiation experiment rooms of Figure V.2 in order beginning with E1.

An online isotope separation device is installed in Experiment Room E1. This is a device that combines a gas-filled recoil isotope separator (GARIS) and an ion guided isotope on-line separator (IGISOL). It is used in the research and separation of rare RI, which has a short life and is generated by target nuclear crushing reactions, multinucleon transfer reactions, and fusion reactions. Its strong points are that it can be used in all basic elements, it is easy to operate stably without an ion source, and while the limit of its short life is short at 0.1 ms in the IGISOL and 1  $\mu$ s in the GARIS, its rate of extraction is relatively high. At present, the separation of superuranium elements is being tested using GARIS. Research is planned to look into the generation of super heavy element nuclei and unstable element nuclei that are far away from the stability zone, using this device. The E1 experiment room has two other beam lines, but at present, there are no plans to install measurement devices for these.

A large-scale scattering tank and an atomic collision experimental device are being built in Experiment Room E2. The large-scale scattering tank is 3 m in diameter, 5

m long, with a table 2 m wide and 4 m long being installed inside. By installing various detectors within, it should be able to measure over the entire azimuth of ( $\theta$ ,  $\phi$ ) the various radiation lines emerging by nuclear reaction. This scattering tank is being designed so that it is possible to divide it up and so it can be used when joined with small scattering tanks. Research into fusion reactions, nucleus division reactions, and multinucleon transfer reactions, all by means of heavy ion, is planned, but the construction of a detector is the task of the future. Incidentally, this device is a general purpose device and can be used for other research.

The atomic collision experimental device contains the following installed in a series with one beam line: a general purpose scattering tank (1 m diameter), a scattering tank used for the measurement of X-ray angle distribution (25 cm in diameter), and an electromagnet with a charged analyzer (1.5 T maximum magnetic field, and a cor path radius of 2.5 m). This beam line is designed taking into consideration the background so that it is extremely low-powered in order to take measurements in a high vacuum. Experiments are already underway in which the radiation electrons captured (REC) are in the range of 20 MeV per nucleon. The results obtained are interesting in connection with the distribution of the quantity of motion of electrons.

Experiment room E3 has two beam lines. For one an RI manufactured device for use in nuclear chemical research is being installed. This is used to generate short life RI by heavy ion radiation. It is equipped with a target in the middle of a metal ball and has a remote operating system to send that target after radiation to a hot lab downstairs safely and swiftly by gravity. This is called the falling ball radiation device. The hot lab downstairs uses nuclei with a short life (a lifespan of less than 2 h), and the various long life nuclei are handled in an RI experiment room in a separate module.

As for the other beam line in Experiment room E3 a device for measuring pi mesons, which emerge by heavy ion reactions, and a crystal ball of a barium fluoride ( $\text{BaF}_2$ ) scintillator are being installed. The former measures a pi meson which is generated by low energy from a threshold value. It made the initial observation in the world of a  $\pi$  generated by low energy of 44 MeV per nucleon. The latter put 88 simple crystals of  $\text{BaF}_2$  together in a row and attempt to overturn half in the space surrounding the target. It lines up five to six square shaped scintillators without a gap, and the interior turns into the shape of a soccer ball. It is used to measure high energy  $\gamma$  rays in addition to simultaneously measuring all the  $\gamma$  rays that emerge when heavy ion collides with the nucleus of an atom.

A high resolution charged particle analyzer (PA) and a neutron analyzer are scheduled to be installed in Experiment room E4. The PA customarily rotates around a target, but this time it is designed so that the injected beam moves. In other words, a large magnet known as a beam swinger rotates with the beam serving as its axis

and can change the direction of the beam to be injected into the target. This is the world's largest beam swinger. It is scheduled to be completed at the end of 1989, and manufacturing is moving forward.

Experiment room E5 is the biological radiation room. One beam line installed is for a wobblers magnetic system that tries to radiate the beam uniformly by circular oscillation. Another beam line is scheduled to be built shortly. The dosimetry of heavy ion radiation and research of cells and animal radiation are being advanced. Incidentally, in preparation for future use, a horizontal radiation room and a vertical radiation room, which will be separate rooms, are being prepared.

Experiment room E6 is the experiment room in which Riken puts the most effort. The heavy ion beam emerging from the ring cyclotron is divided immediately into three beams when it enters beam subdivision room D. Of this, the beam line on the E7 side is the injected nuclei fragment separator, or the projectile fragment analyzer (RIPS). When a high energy heavy ion collides with a target nucleus, part of the injected heavy ion is stripped off (injected nucleus fragment reaction), and the emerging radiated nucleus converge at the front with a speed virtually identical with that of the injected nucleus. RIPS uses this phenomenon to take in emitted nuclei at a high absorption rate and put them out in the form of an RI beam after nuclide separation.

In research of nuclear physics and physical properties based on RIPS, two methods are being studied: (1) causing a secondary nuclear reaction to occur by having the RI beam strike the target nucleus at the final focal surface, and (2) observing the emitted rays along with the decay of RI that is decelerating or stationary. The former is noteworthy as a new field of nuclear physics, such as the research to measure the size and shape of the multi nuclei (or small nuclei) at the very tip, and the research to explain the basic element generation process in heavenly bodies by nuclear reactions caused by unstable nuclei. The latter is used in important research on the decay of unstable nuclei, research of basic physics such as symmetrical destruction in particular, and research into the nuclear properties caused by RI injection. Recently, it was discovered at Riken that this RI beam had a high degree of polarization. Because of this, further great development by the use of the RI beam has begun

to be anticipated. Incidentally, the construction of the measuring device in Experiment room E6 is a future task.

Experiment room E7 is the physical properties research experiment room. Its important equipment are (1) a device (large  $\Omega$ ) to collect light, secondary particles (muons in particular) which are generated by striking a target with heavy ion beams, and (2) a mechanism to generate various ions to be emitted from controlled metal surfaces and a device (slow) to research their use. The former combines three superconductor coils, takes in efficiently secondary particles produced over a wide range, and collects those which enter a fixed quantity of motion. Research into the use of the surface muon is planned.

The above is a summary of the devices developed for the purpose of research by a ring cyclotron. Devices to collect the necessary data and handle the data measured by using these are being prepared.

Many of the devices introduced here have not yet been announced in a formal report. For details, please refer to "Rikken kasokuki shisetsu nenpo [Riken's Accelerator Facility Annual Report]".

#### 4. Conclusion

Riken's accelerator research facility does not have equipment exclusively for the use of institute. They were built as equipment available for the use of outside researchers as well. Problems are called for twice a year. The applications are investigated by a Problem Advisory Council [PAC] made up of experts in the field both from the institute and outside it. This committee then decides on the problems for which experiments will be conducted. Recently, applications for problems were submitted from such foreign countries as the United States, countries in Europe, India, China, and South Korea. As far as we are concerned, we hope that superior research results will emerge from this facility, and we want to contribute to international scientific cooperation. Incidentally, if you are uncertain about the uses of the facility, we hope that you will not hesitate to inquire.

(Received on July 1, 1989)

#### Reference Material

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**R&D Basic Plan for New Themes for FY89**

90CF0082 Tokyo TSUSANSHO KOGYO GIJUTSUIN  
in Japanese Jun 89

[Text] R&D Basic Plan for "Super Environment-resistant Advanced Materials"

**1. R&D period**

From FY89 for 8 years

**2. Funding required to implement R&D**

Efforts will be made to ensure as much R&D funding as possible.

**3. Purpose of R&D**

The purpose is to establish basic technologies involved in super environment-resistant advanced materials which are superior in heat resistance, high specific strength, high specific hardness, and oxidation resistance in high temperature environments. These materials are needed in a broad range of sectors such as aerospace and energy-related equipment.

**4. Goal of R&D**

The goal is to establish basic technologies needed to develop super environment-resistant materials such as intermetallic compounds that are superior in isotropic strength, durability and resistance to oxidation and corrosion in high temperature environments as well as advanced composite materials that are superior in heat resistance and specific strength in high temperatures.

**5. Content of R&D**

- (1) Development of intermetallic compounds
  - (a) Development of high specific strength intermetallic compounds
    - (i) Material design
    - (ii) Creation and processing technologies
  - (b) Development of high fusion point intermetallic compounds
    - (i) Material design
    - (ii) Creation and processing technologies
- (2) Development of advanced composite materials
  - (a) Development of heat-resistant reinforced fiber
    - (i) Development of carbon fiber
    - (ii) Carbon fiber surface coating technology
    - (iii) Development of silicone carbide lineage fiber
  - (b) Composite material of carbon fiber and base material of carbon lineage
    - (i) Improve material properties
    - (ii) Improve resistance to oxidation
    - (iii) Composition and formation technologies
  - (c) Fiber-reinforced intermetallic composite materials
    - (i) Interfacial reaction control technology
    - (ii) Composition and formation technology

- (3) Development of evaluation technology, material evaluation

- (i) Heat performance evaluation
- (ii) Dynamic performance evaluation
- (iii) Chemical performance evaluation

**6. R&D methodology**

The project will be divided into two phases, each with a duration of 4 years, and the R&D emphasis of each phase will be as follows:

- (1) Development of intermetallic compounds

Phase 1 (FY89 - 92)

Material design of high specific strength intermetallic compounds and development of technology to create and process the designed materials.

Design of high fusion point intermetallic compounds and basic study of technology to create and process the designed materials.

Phase 2 (FY93 - 96)

With results of phase 1 as a base, efforts will be made to upgrade material design, and technology to create and process the materials will be established.

- (2) Development of advanced composite materials

Phase 1 (FY89 - 92)

Heat-resistant reinforced fibers will be developed and a basic study will be conducted of the technologies for composition and formation of intermetallic compound composite materials as well as composite materials composed of carbon fiber and a base material of carbon lineage.

Phase 2 (FY93 - 96)

With results of phase 1 as a base, efforts will be made to upgrade heat-resistant reinforced fibers and composition and formation technologies will be established.

- (3) Development of evaluation technology and material evaluation

Phase 1 (FY89 - 92)

A study will be conducted of technology to evaluate thermal, dynamic and chemical performance in super high temperatures.

Phase 2 (FY93 - 96)

With results of phase 1 as a base, technology for evaluation of performance in super high temperature will be established and evaluative testing of the developed materials will be conducted.

A parallel development formula will be adopted for R&D to optimize R&D implementation. We will try to achieve flexible and smooth advances in R&D by fully



Research Topic		1989	1990	1991	1992	1993	1994	1995	1996
Development of intermetallic compounds	Development of high specific strength intermetallic compounds	Material design: development of creation and processing technologies				Material design for composite materials; establishment of creation and processing technologies			
	Development of high fusion point intermetallic compounds	Material design: basic study of creation and processing technologies				Upgrading of material design; establishment of creation and processing technologies			
Development of advanced composite materials	Development of heat-resistant reinforced fibers	Development of heat-resistant reinforced fibers; basic study of surface coating technology				Upgrading of heat-resistant reinforced fibers; establishment of surface coating technology			
	Composite materials of carbon fiber/carbon base material	Development of matrix; basic study of composition and formation technologies, coating technology				Upgrading of matrix, establishment of composition and formation technology and coating technology			
	Fiber-reinforced intermetallic composite materials	Basic study of interfacial reaction control technology, composition and formation technologies				Establishment of interfacial reaction control technology, composition and formation technology			
Development of evaluation technology; material evaluation		Basic study of technology to evaluate thermal, dynamic, and chemical performance				Establishment of technology to evaluate thermal, dynamic and chemical performance; conducting of evaluation tests			

### Reference 3: Long-term R&D Plan

assessing the status and results of R&D at each of the above stages and by comprehensively studying and assessing progress, domestic and overseas R&D trends and the status of acquisition of funding for R&D.

Also, to proceed efficiently with R&D, there will be full, comprehensive discussions and exchanges of information among all the parties responsible for carrying out research on individual topics and qualitative research cooperation will be carried out. Research results will be made public, both in Japan and abroad.

### Reference 1: Necessity for R&D

As we face the beginning of the 21st Century, various projects are underway, such as the space plane and the supersonic transport (SST)/hypersonic transport (HST) in the aerospace sector and coal gasification power generation and nuclear fusion in the energy sector. To realize these projects, it is essential to have structural materials that can satisfy all sorts of requirements for performance in harsh environments which are impossible for existing materials. These include heat resistance, high specific strength, high specific hardness and

resistance to oxidation. Of greatest need is the development of lightweight structural materials that can withstand temperatures as high as 1,000-2,000°C so that they can be used to build space plane parts, gas turbine moving blades and fusion reactor walls.

However, required properties such as heat resistance and high specific strength cannot be fulfilled by one developed material alone and it will be necessary to develop various types of materials that are appropriate for the area of use. The development of super environment-resistant advanced materials such as intermetallic compounds and advanced composite materials is needed to produce these required properties.

Since the realization of such super environment-resistant materials is accompanied by risks of large amounts of research funding and long research periods, it is difficult for private companies to proceed independently with R&D on such materials. Also, it is necessary to carry out material design, material evaluation and other research concerning material properties at the same time as R&D that is geared to application, such as materials technology, and close tie-ins among government, industry and the universities are extremely important.

**Reference 2: Outline of R&D****(1) Development of intermetallic compounds****(a) Development of high specific strength intermetallic compounds**

We will draw up a state of equilibrium chart and carry out material design to improve normal temperature ductility (durability), high temperature hardness and other properties.

We will develop melting technology that will enable high-purity, high-precision adjustment of constituents and casting technology that will incorporate advanced properties molding material and control of solidification and crystallization.

We will develop powder manufacturing technology that will enable control of powder grain diameter and constituents and technology to form materials from powder that will enable control of crystal grain diameter.

We will develop surface treatment and other technologies to improve resistance to oxidation.

**(b) Development of high fusion point intermetallic compounds**

We will draw up a state of equilibrium chart and search for plural lineage chemical compounds, and along with this, we will carry out material design to improve ductility and upgrade other properties.

We will develop melting technology that will enable high-purity, high-precision adjustment of constituents and casting technology that incorporates molding material with advanced properties and solidification and crystallization control.

We will develop powder manufacturing technology that will enable control of powder grain diameter and constituents and technology to form materials from powder that will enable control of crystal grain diameter.

We will develop surface treatment and other technologies to improve resistance to oxidation.

**(2) Development of advanced composite materials****(a) Development of heat-resistant reinforced fibers**

We will develop high-strength carbon and silicone carbide lineage continuous fiber with superior resistance to heat and oxidation, and along with this, we will develop surface coating technology in order to upgrade resistance to oxidation.

**(b) Composite material of carbon fiber and base material of carbon lineage**

We will develop a new matrix with high carbon yield, then develop composition and formation technology to get the matrix to permeate between the fibers in a dense and uniform manner. We also will develop coating technology that will improve resistance to oxidation.

**(c) Fiber-reinforced intermetallic composite materials**

We will develop technology to control interfacial reaction between fibers and matrix and new composition and formation technology.

**(3) Development of evaluation technology; material evaluation**

We will develop technologies to evaluate thermal, dynamic and chemical performances in super high temperature environments, and we will evaluate and test the developed materials.

**Reference 3: Effects of R&D****1. Aerospace sector**

The space plane will fly at speeds over mach 5 and the temperature of the fuselage is expected to reach 1,800°C during passage through the atmosphere. The nose and front edge of the main wings of the SST/HST are expected to reach high temperatures for long periods of time. Moreover, higher engine combustion temperatures are required to provide greater propulsion. It is anticipated that using super environment resistant advanced materials as construction materials will greatly increase the possibility of realizing the space plane and the SST/HST.

**2. Energy sector**

Super environment-resistant advanced materials are superior in resistance to heat and radiation, qualities that are needed for coal gasification power generation, atomic reactors and nuclear fusion reactors. They will make it possible to achieve major improvements in qualities needed in the energy sector, and novel designs, increased reliability and increased automation are anticipated.

**3. Primary shaping materials manufacturing process sector**

Equipment such as super high temperature furnaces, smelting furnaces, hotpress and hot isostatic press (HIP), which are used in primary shaping materials manufacturing processes, must be able to withstand temperatures of 2,000°C. The development of super environment resistant advanced materials will make it possible to improve reliability and performance of these primary shaping materials manufacturing processes, and expansion of the primary shaping materials manufacturing sector is anticipated.

**Non-linear Electronic Materials for Optical Communications**

90CF0082B Tokyo TSUSHANSHO KOGYO  
GIJUTSUIN in Japanese Jun 89

[Text] R&D Basic Plan for Non-linear Optoelectronic Materials

**1. R&D period**

From FY89 for 10 years

## 2. Funding required to implement R&D

Efforts will be made to ensure as much R&D funding as possible.

3. Purpose of R&D The purpose is to establish basic technologies concerning non-linear optoelectronic materials that exhibit a non-linear form of response to light and can be used in such equipment as optical logic switches based on the modulation, amplification and change in refraction index of light.

## 4. Goal of R&D

The goal is to establish basic technology in order to search for primary materials that have high tertiary non-linear sensitivity and high-speed responsiveness and to create non-linear optoelectronic materials.

## 5. Content of R&D

- (1) Elucidation of the structure of manifestation of the non-linear optical phenomenon
- (2) Development of primary materials
  - (i) Organic type materials
  - (ii) Dispersion type materials
- (3) Development of technology to create materials
  - (i) Crystal growing technology
  - (ii) Technology to create dispersion
  - (iii) Superlatticing technology
- (4) Development of evaluation technology, material evaluation

## 6. R&D methodology

The project will be divided into Phase 1 (4 years), Phase 2 (3 years) and Phase 3 (3 years) and the R&D emphasis of each phase will be as follows:

### Phase 1 (FY89-92)

To develop new materials, we will elucidate the structure of the non-linear phenomenon and search for or design various types of primary materials. Along with this, we will conduct studies of primary material synthesis technology, material creation technology and evaluation technology.

### Phase 2 (FY93-95)

We will elucidate the structure of the non-linear phenomenon and synthesize various types of materials. Along with this, we will develop evaluation technology.

### Phase 3 (FY96-98)

With results achieved through Phase 2 as a base, we will develop materials, integrate component technologies such as the technology for creating materials, and achieve the characteristics of high-performance non-linear optoelectronic materials. Along with this, we will evaluate the characteristics of the materials.

A parallel development formula will be adopted for R&D to optimize R&D implementation. We will try to

achieve flexible and smooth advances in R&D by fully assessing the status and results of R&D at each of the above stages and by comprehensively studying and assessing R&D progress, domestic and overseas R&D trends and the status of acquisition of funding for R&D.

Also, to proceed efficiently with R&D, there will be full, comprehensive discussions and exchanges of information among all the parties responsible for carrying out research on individual topics and qualitative research cooperation will be carried out. Research results will be made public, both in Japan and abroad.

## Reference 1: Necessity for R&D

Because of the increase in diversity of information, there is a great need for rapid upgrading, both in quality and quantity, of communication and data processing technologies. To transmit and process large volumes of data, it is necessary to increase the capacity and speed of data processing equipment. In existing communication and data processing systems, amplification, logic, memory and switching functions are accomplished by adding non-linear manipulations to electrical signals. However, for some electrical signals, it has become impossible to exceed certain limits to further acceleration. Attention has become focused on the use of optical technology to break through this barrier.

At present, optical technology still is in a basic stage where it is being used only for the transmission path for optical communications. The elucidation of the basic principles for advanced use of the non-linear behavior of light has just begun. In the next generation of communication and data processing equipment that fully demonstrate the superior qualities of light, such as speed and parallelism, we want to be able to carry out advanced functions through the use of optical technology that will equal or surpass electrical signal processing. To achieve that, the development of technology for non-linear optoelectronic materials with advanced functions is necessary.

Non-linear optoelectronic materials are new optical function materials that use non-linear response to light at the atomic and molecular level of a substance, and materials that have various superior features, such as large non-linear constant, high-speed responsiveness, and stability vis-a-vis laser beams, are being sought.

However, since the realization of such advanced non-linear optoelectronic material, from the search for primary materials to the creation of the materials, is accompanied by risks of large amounts of research funding and long research periods, it is difficult for private companies to proceed independently with R&D on such materials. Also, elucidation of the structure of the non-linear optical phenomenon, material evaluation and other research concerning material properties must be carried out at the same time as R&D that is geared to application, and close tie-ins among government, industry and the universities are extremely important.

Research Topic		1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Discovery of manifestation mechanism of non-linear optical phenomenon		Research on non-linear phenomenon response speed, etc				Discovery of elements of existing structure			Material design guidelines to achieve advanced functions		
Primary materials	organic	Search for primary materials, molecular design				Establishment of synthesis, polymerization technologies			Integration of component technologies		
	dispersion-type	Microscopic particles; search for base materials; study of adjustment, methods				Microscopic particles and base material synthesis; establishment of dispersion technology					
Development of technology to create materials		Development of crystal growth, fine particle dispersion and super latticing technologies				Establishment of structurally controlled crystal growth technology, even dispersion technology, superlatticing technology					
Development of evaluation technology; material evaluation		Establishment of basic technology to evaluate non-linear optical characteristics				Development of new technology to evaluate materials			Establishment of material evaluation technology		

Reference 3: Long-term R&amp;D Plan

## Reference 2: Outline of R&amp;D

## (1) Elucidation of the structure of manifestation of non-linear optical phenomena

We will elucidate the structure of manifestation of non-linear optical phenomena such as induction and diffusion, changes in wavelength, refraction index changes and absorption rate changes, and we will look into the relationship between time factors, such as high-speed responsiveness and the relaxation phenomenon, and the creation of material functions. Along with this, we will search for new non-linear optical phenomena. Based on this knowledge, we will establish design guidelines for non-linear optoelectronic materials with more advanced functions.

## (2) Primary material development

(a) Organic primary materials: We will apply molecular design that takes atomic and molecular configuration into consideration, search for low and high molecule organic primary materials that display strong non-linear functions and high-speed responsiveness, and develop technology for synthesizing these materials.

(b) Dispersion-type primary materials: We will conduct a search for dispersion-type primary materials—in which structurally controlled microscopic particles such as organic molecules and semiconductors have been distributed in an organic or glass lineage matrix material—

that display strong non-linear function and high-speed responsiveness; and we will develop adjustment (design and synthesis) technology.

## (3) Development of technologies to create materials

(a) Crystal growth technology: We will develop technology to grow organic crystals with the size, completeness and form that can adequately manifest the non-linear function.

(b) Dispersion technology: We will develop dispersion technology to evenly and densely distribute structurally controlled microscopic particles in matrix materials.

(c) Superlatticing technology: We will develop technology for second and third dimensional superlatticing of atoms and molecules.

## (4) Development of evaluation technology; material evaluation

We will develop technologies to evaluate material functions such as technology to structurally evaluate non-linear optoelectronic materials, technology to evaluate and measure the non-linear optical index, and technology to measure optical response speed.

## Reference 4: Effects of R&amp;D

In the communications sector, the development of advanced function non-linear optoelectronic materials will enable the application of wavelength conversion,

amplification and short pulse creation to light modulation devices. In the data processing sector, it will enable application to optical logic switches, optoelectronic memory and optical associative memory. This is expected to advance the realization of super high-speed large capacity communications that use unique optical features such as high speed in the time domain and parallel processing in the spatial domain and to advance R&D on optical computers.

Additionally, the technology to design electron structure and atomic and molecular configuration, as well as technologies to create materials that will be established through this R&D plan, such as crystal growth, distribution and superlattice, are basic technologies common to the development of many materials, and are expected to have a far-reaching effect on a broad range of sectors, from development of materials with revolutionary physical properties and functions to development of materials with chemical functions.

### **In-vitro Protein Synthesis Technology**

90CF0082 Tokyo TSUSHANSHO KOGYO  
GIJUTSUIN in Japanese Jun 89

[Text] R&D Basic Plan for Functional Protein Aggregates Applied Technology

#### **1. R&D period**

From FY89 for 10 years

#### **2. Funding required to implement R&D**

Efforts will be made to ensure as much R&D funding as possible.

#### **3. Purpose of R&D**

The purpose is to establish basic technologies concerning the artificial reconstruction of functional protein aggregates that will enable self-controllable chemical reaction processes and selective, specific composite multi-phased reactions in order to engineer the reproduction of the composite functions possessed by functional protein aggregates.

#### **4. Goal of R&D**

The goal is to engineer the reproduction of functions possessed by organic membranes and other functional protein aggregates, such as production, conversion and recognition of matter and selective permeation and transporting, and to develop technologies to create artificial functional protein aggregates that can realize, as controllable chemical processes, material conversion and production reactions with high selectivity and specificity.

#### **5. Content of R&D**

The following R&D will be carried out to achieve these goals:

- (1) Analysis and evaluation of the structure and functions of functional protein aggregates

- (2) Extraction, separation and refining of functional protein aggregates from organic materials
- (3) Stabilization and alteration of functional proteins and lipids and development of artificial materials
- (4) Artificial reconstruction of functional protein aggregates
- (5) Evaluation

#### **6. R&D methodology**

The program will be divided into Phase 1 (4 years), Phase 2 (3 years) and Phase 3 (3 years), and the R&D emphasis of each phase will be as follows:

##### **Phase 1 (FY89-92)**

We will search for materials appropriate for reconstruction from organic membranes and other in-vivo functional protein aggregates, and along with this, we will establish basic conditions for appropriate analysis and evaluation of their functions and structure.

Additionally, we will conduct a basic study on component technologies that are needed for artificial reconstruction of functional protein aggregates.

By the end of Phase 1, we will establish specific and final goals for R&D.

##### **Phase 2 (FY93-95)**

Based on the information and materials selected in Phase 1, we will establish component technologies (including technologies to alter and stabilize functional proteins and lipids in accordance with use as well as development and use of appropriate artificial materials) with the aim of artificial reconstruction of functional protein aggregates.

##### **Phase 3 (FY96-98)**

We will artificially reconstruct functional protein aggregates that have a high degree of ability to create composites; and we will evaluate their structure and functions.

A parallel development formula will be adopted for R&D. If necessary, a concentrated research formula also will be incorporated. We will try to achieve flexible and smooth advances in R&D by fully assessing the status and results of R&D at each of the above phases and by comprehensively studying and assessing progress in R&D, domestic and overseas R&D trends and the status of acquisition of funding for R&D.

Also, to proceed efficiently with R&D, there will be full, comprehensive discussions and exchanges of information among all the parties responsible for carrying out research on individual topics and qualitative research cooperation will be carried out. Research results will be made public, both in Japan and abroad.

**Reference 1: Necessity for R&D**

1. In recent years, the matter of application of bioprocesses to chemical engineering is being addressed actively in order to revolutionize chemical engineering processes. Recombinant DNA technology has made it possible to mass-produce useful enzymes that had not been available in large quantity, and it is becoming possible to manufacture a variety of new and useful substances by creating bioreactor systems from microorganisms that were bred and improved through the use of these enzymes and recombinant DNA technology.

2. However, when enzymes are used in existing bioreactors, normally it is possible only to produce and convert substances based on single-phase reactions with one type of enzyme. Moreover, when a microscopic biomass is used, its recognition capability and selectivity are used in "black box" form, as it were, and human control of the reaction is virtually impossible.

3. In order to engineer the reproduction of advanced biofunctions and use them industrially, it has become extremely important to artificially reconstruct advanced composite functions such as "substance conversion, substance production, substance recognition, and selective permeation and transporting," which are possessed by organic membranes and other functional protein aggregates, and to build "aggregates" that can realize substance production and conversion reactions with high selectivity and specificity through composite multi-phased reactions or in self-controllable form.

4. As a new technology that will revolutionize the industry of the next generation, there is hope for the establishment of technology to build bioprocesses that can reproduce advanced functions such as "self-control capability," which is the most important characteristic of organisms, for example the construction of functional protein aggregates that can control reactions on their own and have the ability to judge external information (such as chemical information).

**Reference 2: Outline of R&D**

1. Analysis and evaluation of structure and functions of functional protein aggregates

(1) We will develop technologies for analysis and evaluation through spectroscopic methods that divide light into visible, ultraviolet (UV) and infrared (IR) light.

(2) We will develop analysis and evaluation technology using tunnel microscopes, interatomic power microscopes and other new physical measuring instruments.

(3) We will develop technologies to analyze and evaluate biological functions through immunological and specific probing methods.

2. Extraction, separation and refining of functional protein aggregates from organic material

We will develop the technology to isolate and refine functional proteins, lipids and their aggregates from organic materials while retaining their capabilities. That is, we will develop technologies to make organic membranes soluble and to refine hydrophobic proteins and lipids.

3. Stabilization and alteration of functional proteins and lipids; development of artificial materials

We will develop technologies to alter and stabilize functional proteins, lipids and their aggregates, which have been isolated and refined, through genetic engineering, protein engineering and chemical modification so that they are suitable for artificial reconstruction. We also will develop artificial materials with the required functions that can be used for reconstruction.

4. Artificial reconstruction of functional protein aggregates

Through the development of technologies for (1) use of Langmuir-Blodgett film and ribosomes, (2) use of electrical and magnetic fields, (3) use of the antigen-antibody reaction, (4) use of self-aggregation capability of proteins, and (5) use of molecular manipulation by physical methods, we will develop technologies to artificially construct functional protein aggregates with optional capabilities. Additionally, based on the developed technologies, we will attempt to build a model system for self-controllable substance production and conversion.

**Reference 4: Effects of R&D**

Through successful development of "applied technology for functional protein aggregates," technologies for analyzing the structure and functions of in-vivo functional protein aggregates and for molecular level handling will be developed, and the advanced composite functions of organisms, which until now have been used in "black box" form, can be designed and reconstructed to suit specific purposes and used industrially. It is expected that this will promote the application of organic functions to a broad range of industrial sectors and contribute to the realization of, for example, the following:

1. A chemical engineering system that will select only the necessary matrix from a mixed material and incorporate it into a reactor system, and after a composite multi-phase reaction, excrete just the required product from the system in pure form.

2. The manufacturing of fine chemical products (such as physiologically active glycoprotein with a complex side chain) with extremely complex structures that are impossible to produce through existing chemical engineering and bioprocesses.

Research Topic	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Analysis and discovery of aggregate structure and functions	Development of measuring instruments; study of measurement conditions				Measurement and evaluation of organic materials			Analysis and evaluation of reconstructed aggregates		
Extraction, separation and refining of aggregates	Retrieval and extraction of functional protein aggregates				Establishment of separation and refining technologies					
Stabilization and alteration of proteins and lipids;	Discovery of membrane protein stabilization mechanism				Protein alteration and chemical modification					
Development of artificial materials	Discovery of lipid functions; development of synthetic lipid				Lipid alteration and modification					
Artificial reconstruction of functional protein aggregates	Basic research using model substances				Development of substrate for use in reconstruction			Construction and evaluation of artificial aggregates		
					Organic material reconstruction technology					

Reference 3: Long-term R&D Plan

**National Research Institute for Metals FY88 Annual Report**

90cf0243a Tokyo KINZOKU ZAIRYO GIJUTSU  
KENKYUSHO NENPO in Japanese Sep 89 pp 5-201

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#### 1. Summary

The National Research Institute for Metals (NRIM) considers its mission to promote a creative source form of basic and leading research, to raise the potential of knowledge and technology, to meet the public needs with

national projects as the core research agency concerning materials problems, to open and offer to the public its research results and potential as an institute widely open to society, and to contribute to society.

To accomplish this mission, NRIM promotes 1) research to develop new materials which have new properties and high performance, with priority to unexplored fields such as rare metals, intermetallic compounds, and artificial and special structural substances, as well as 2) conduction of basic research related to the establishment of material reliability in order to ensure the reliability and safety of instruments and structures which support the foundation of national life and industrial activity and further advance it, along with research cooperation through organic cooperation with industry, academia, and government and research exchanges based on an international research cooperation system.

In fiscal 1988, for a research structure which probes and unearths basic, creative sources and carries out the advancement of specialized research capability and technology, and for research problems in special fields, the research structure has been reorganized into a research group structure that conducts research integrating the results and capabilities of the research departments and research has been conducted with a new organization consisting of a management department, 10 research departments, and 5 research groups with 437 authorized personnel (among which 333 are research positions).

The specific research organization and research system is indicated below.

#### Research Department System

**Basic Physical Properties Research Department:** Basic research relating to the probing of new phenomena and latent physical properties and bringing out universal principles controlling the physical properties of substances and materials.

**Functional Properties Research Department:** Clarification of discovered mechanisms of the functional properties of materials and basic research concerning upgrading properties.

**Mechanical Properties Research Department:** Clarification of discovered mechanisms of the mechanical properties of materials and basic research concerning upgrading properties.

**Materials Design Research Department:** Research concerning development of materials design methods based on theories and experiments related to materials structure, texture and properties.

**Reaction Control Research Department:** Research concerning chemical reaction control technology for synthesis of new substances.

**Surface/Interfacial Control Research Department:** Research concerning control of surface and interfacial form, structure, and texture of substances and materials.



Texture Control Research Department: Research concerning control of material texture using melting and solidification or solid phase transformation and diffusion.

Measurement Analysis Research Department: Development of substance and material structure and texture measurement analysis technology and research on those applications to new materials and information processing concerning them.

Damage Mechanisms Research Department: Clarification of material damage and deterioration mechanisms and research concerning that detection technology.

Environmental Performance Research Department: Research concerning material properties evaluation technology under various kinds of environments.

#### Research Group Structure

First Research Group (New Superconducting Materials): Research concerning development and evaluation of new superconducting materials.

Second Research Group (New Reactor Materials): Research concerning nuclear fusion reactor and other new reactor materials.

Third Research Group (Intermetallic Compounds): Research concerning development of transition metal and Al and Si intermetallic compound properties.

Fourth Research Group (Special Powders): Research concerning special powders and invention of their binders and their properties.

Fifth Research Group (Material Life Forecasting Technology): Research concerning establishment of basic materials life forecasting technology.

Research work is conducted on 56 project research topics, 49 ordinary research topics and 2 survey research topics.

The summary of these is given below.

#### Special Research

NRIM conducts unique and particularly large-scale research on the following four topics:

1. Research concerning the development of intermetallic compound materials for high performance luminous elements.

Development of new intermetallic compound materials to realize ultra thin film multilayering of intermetallic compounds, laser elements for very long distance light communications, visible light luminous elements and other high performance luminous elements.

2. Basic research concerning material non-contact evaluation methods by laser beam.

With the objective of establishing new methods to evaluate materials that are non-destructive and non-contact using laser beams, an attempt to establish non-contact evaluation technology comprised of inducement of elastic waves in the material by laser beam and reception of the elastic waves transmitting information on the material interior.

3. Research and development of apparatus materials using ultra low temperatures.

Development of high performance superconducting materials necessary for various kinds of apparatus using superconduction such as superconducting generators, energy storage, magnetic floating trains, and high energy accelerators, ultra low temperature structural materials, and ultra low temperature magnetic materials, and research on integrating these and making them serviceable.

4. Research concerning the development of lightweight heat-resistant intermetallic compound materials.

With the objective of developing high temperature structural materials used in aviation and space as well as energy-saving related apparatus, research on upgrading quality such as improving the ductility and processability of lightweight TiAl-base intermetallic compound materials.

#### Nuclear Research

With national institution nuclear test research funds, development of metal materials used in fast breeder reactors and nuclear fusion reactors, leading-edge basic research on using nuclear energy and research from the viewpoint of ensuring the safety of light water reactors are being conducted. The following 10 topics are being carried out, maintaining cooperation with nuclear energy related research institutions.

1. Research concerning development of high performance intermetallic compound materials for nuclear energy.

Aiming at the development of new materials appropriate for use in a hazardous environment centering on reactors, investigation and invention of intermetallic compound materials having irradiation resistance, heat resistance, corrosion resistance and highly functional.

2. Research concerning corrosion resistance of nuclear fuel reprocessing equipment welded parts.

With regard to corrosion resistance of nuclear fuel reprocessing equipment, particularly in welded parts which have become a problem, clarification of the relationship of corrosion resistance and welded part properties in an attempt to upgrade further that corrosion resistance safety, and clarification of the quality of properties to be sought in welded parts from the point of corrosion resistance.

3. Research concerning evaluation of low temperature brittleness of metal materials used in nuclear fuel transport containers.

Establishment of evaluation methods for low temperature brittleness of transport container materials based on dynamic fracture toughness to ensure safety of nuclear fuel transport containers under low temperature weather conditions.

4. Research concerning evaluation of corrosion resistance of artificial barrier materials in stratum disposal.

Development of corrosion measurement and monitoring technology as well as life evaluation estimation methods in connection with evaluation of durability of artificial barrier materials which are considered a problem in stratum disposal promotion programs for high level radioactive waste materials.

5. Research concerning properties of new superconducting wire for nuclear fusion reactors.

Basic research concerning technology to test superconducting wire properties under a nuclear fusion environment (in superfluid helium, under repeated stress, under fluctuating magnetic field, and under neutron irradiation).

6. Research concerning low induced radioactive materials.

With reduction of induced radioactivity of structural materials in a fast neutron irradiation environment as the objective, development of iron-base alloys superior in phase stability, high temperature strength, toughness, and irradiation resistance as well as an attempt to establish a technology base for manufacture of composite materials which can expect rather low induced irradiation.

7. Research concerning in situ analysis and evaluation technology of material irradiation damage.

Conduct in situ dynamic observation at the atom level at the same time as irradiation damage is being given to the surface and interior of materials, applying ion and electron beam technology to clarify exactly the irradiation damage mechanism occurring at the atom level and material behavior caused by it, and develop a "material irradiation damage in situ analysis and evaluation device," a device that will swiftly perform a status analysis and structural analysis.

8. Research on material strength and life forecasting technology under an irradiation environment using an ion beam.

With the objective of establishing evaluation and forecasting technology for strength and life under an irradiation environment directed at increasing the reliability and safety of nuclear fusion reactor and other new reactor structural materials, aim to establish a technology base for forecasting material life in a radiation

field using theoretical models and computer simulation, along with development of basic technology for comprehensive evaluation of deformation and destruction behavior under irradiation by use of an ion beam.

9. Research concerning advancement in evaluation of damage and life of structural materials for high temperature gas reactors.

With the objective of establishing technology for evaluation of damage and life in atmospheric super high temperature, noting generation of cracks and growth behavior, clarification of the generation of creep cracks and growth behavior under the static load of heat-resistant alloys for high temperature gas reactors from the metal physics and fracture mechanics standpoints, and development of strength evaluation and life evaluation technology.

10. Research concerning corrosion fatigue—stress corrosion cracks interaction of metal materials for light water reactors.

Conduction of repeated testing of corrosion fatigue—stress corrosion cracks for pressure vessel steel in a light water reactor coolant simulated environment to evaluate the soundness of light water reactor structural materials, and investigation of acceleration phenomena. Also, investigation of influence of mechanical factors and environmental factors exerted on generation and progression of cracks and contribution to quantitative evaluation of these influential factors and confirmation of a safety margin.

#### Material Strength Data Sheets

Creep data and fatigue data has been systematically acquired over a long time to form a base on the safety and reliability of metal materials used in various kinds of machines and structures. After analysis and evaluation, they are published at home and abroad as creep data sheets and fatigue data sheets, respectively.

#### Fatigue Data Sheet Compilation (III)

A standard fatigue strength data sheet is compiled to form a base for the proper use and safe design of domestically manufactured, practical metal materials used in machines and structures in which fatigue damage has become a problem.

#### Creep Data Sheet Compilation (III)

Creep breaks, creep deformation and relaxation tests are systematically conducted on heat-resistant metal materials used over a long period of time in various kinds of high temperature apparatus and by analysis, evaluation, and publication of the acquired data, contribution is made to ensuring the safety and upgrading the reliability of high temperature apparatus along with establishing a base for materials development.

Science and Technology Promotion and Coordination Funded Research (General Research)

Research conducted with concerted effort under the organic cooperation of industry, academia, and government with science and technology promotion and coordination funds, assigned to the following eight topics:

1. Research concerning basic technology on the development of gradient functional material for thermal stress relaxation.

Along with establishing the basic conditions for inventing materials whose composition can be graded to relax thermal stress as well as the joint composition gradient distribution of the material obtained, obtain a guide for establishing basic technology for continuous laminate molding from metal to ceramics by plasma spraying method.

2. Research concerning knowledge base system for support of chemical substance design.

The study of conditions which are a problem to the development of a data base and knowledge base system, with a knowledge base system in mind specifically operating for heat resistant alloys and intermetallic compounds, and an attempt to build an entire system.

3. Research concerning clarification of physical, chemical, and biological phenomena under a microgravity environment through international cooperation.

Based on international cooperation, the conduction of ground tests concerning the relationship with crystallization of diffusion in melts, polarized crystal composite texture particle dispersion mechanisms and flow within melts and contribution to the clarification of these physical phenomena in microgravity.

4. Research concerning basic technology for the invention of new functions through highly purified rare metals.

Discover latent functions possessed by rare metals as well as their compounds which are indispensable metal materials for the development of leading edge science technology and have as the objective, development of high purification technology as well as the invention of new functions with highly purified rare metals or their compounds to find various kinds of new functions for electronic materials, magnetic materials, and optical materials.

5. Research concerning basic technology for invention of new materials by hybrid structural design technology (II).

Development of hybrid structural technology combining chemical bonds and controlled at the atom and molecule level, and contribution to the efficient development of new materials which possess new functional properties.

6. Research concerning development of ultra high vacuum generation, measurement, and utilization technology.

Recently, measurement technology for material surfaces and interfaces has rapidly progressed and along with the development of atomic order control technology for invention of new materials represented by artificial lattices, the easy generation of an ultra high vacuum under  $10^{-10}$ Pa is desired. In this research, a low gas release vacuum vessel will be created using new surface treatment methods such as the surface precipitation method and an ultra high vacuum device will be trial manufactured.

7. International joint research concerning new materials test evaluation technology.

Establish test evaluation technology for superconducting materials and ultra low temperature structural materials which are important new materials, along with common, basic surface chemical analysis and test evaluation technology for mechanical properties under high temperature and high temperature sulfuric corrosion, and conduct international round robin tests, and attempt standardization. Also, conduct a survey to promote reciprocal use of data bases in each nation.

8. Research concerning development of ultra high temperature generation, measurement, and utilization technology.

As a link in the development of technology utilizing ultra high temperature, synthesize composite very fine particles used in thermal plasma and along with evaluating their numerous properties, contribute to making these into binders and developing new functional materials such as sensors and catalysts.

Science and Technology Promotion and Coordination  
Funded Priority Basic Research

Institute research to find sources of revolutionary technology at the discretion of the institute director is conducted on the following six topics:

1. Basic research concerning micro composite technology used in CVD methods.

The properties of particle dispersed materials can be improved by controlling the micro texture using composite powders. A study of the technology here to create composite powders by combining fluidized bed and CVD.

2. Basic research concerning technology for invention of semiconductor quantum well fine lines.

Attempt to create semiconductor quantum well fine lines beam by manufacture of new monocrystal substrate and use of molecular beam epitaxial crystal growth method.

3. Basic research concerning clarification of unique electrical conductivity change mechanisms in thin film surfaces by ion beam method.

Clarify electrical conductivity detection and loss process by in situ measurement of conduction transition phenomena of compound materials including oxides along with introducing element injection and irradiation defects by ion beam method.

4. Research concerning composite material deformation and fracture behavior analysis with supersonic wave microscope.

Observation of composite materials (CFRP, FRM) lining up only one layer of carbon or boron ceramic fibers using a supersonic wave microscope, investigation of the fracture of strengthened fibers inside as well as deformation and fracture behavior of the base, analysis by finite element method and acquisition of basic data on composite material deformation and fracture behavior analysis.

5. Research concerning measurement of material damage element process and clarification with electron beam lithography.

Develop electron beam moire technique to make possible observation of micro deformation behavior of micro discontinuous parts such as grain boundary inclusions, between matrixes, and between grain boundary cavities and matrixes based on electron beam lithography and clarify material damage generation element processes.

6. Research concerning manufacture of intermetallic compounds by combustion synthesis method.

Synthesize and manufacture intermetallic compounds which are difficult to manufacture by existing manufacturing methods applying the combustion synthesis method.

Science And Technology Promotion and Coordination Funded Important Individual Joint International Research

Research is conducted on the following two topics in an attempt at efficient promotion of joint research conducted on the basis of international research cooperation systems agreed upon at the government level such as the Science and Technology Cooperation Agreement.

1. Research concerning gallium gasification extraction properties.

Conduct a basic study concerning the possibility of a gasification recovery process for gallium included in molten iron in the form of a low grade oxide ( $Ga_2O$ ).

2. Research concerning super strong magnetic field magnets.

Conduct a study in the materials aspect and systems aspect in an attempt at optimum design of a super strong magnetic field magnet system.

Science And Technology Promotion and Coordination Funded Urgent Commissioned Research

The following one topic was conducted in response to a request for urgent commissioned research by private enterprise:

Urgent research concerning manufacture as well as forming and sintering of aluminum alloy fine powder by high pressure liquid spray method.

Research was conducted on optimum spray conditions and sintering properties with regard to manufacture of aluminum alloys by the high pressure liquid spray method.

#### Directed Research

After special research has been completed, necessary follow-on research to accomplish fully the initial research objectives or research in which further results can be anticipated by priority implementation, given satisfactory results at the ordinary research stage were conducted on the following six topics:

1. Research concerning titanium alloy toughness mechanism and upgrading its properties.

Clarification of high specific strength and high toughness detection mechanism targeted at titanium alloys which are high specific strength materials and attempt to upgrade properties by combining those applications along with various kinds of processing technologies.

2. Research concerning gallium and other valuable metal extraction technology.

In an attempt to utilize comprehensively complex ores containing rare metals such as gallium, conduct a theoretical and technological study concerning methods to extract, separate, and refine these elements efficiently.

3. Research concerning plasma resistance and irradiation resistance properties of nuclear fusion reactor first wall material.

With development of nuclear fusion reactor first wall materials and peripheral materials as the objective, clarify the active hydrogen isotope and material adsorption mechanism along with obtaining basic information to develop super heat resistant, high thermal conductivity materials and furthermore, attempt to upgrade the ion resistance and neutron irradiation resistance properties by texture control materials.

4. Invention of functional intermetallic compounds and evaluation of properties.

Along with probing the physical properties of intermetallic compounds and their control methods to invent new functional materials using the various unique characteristics included in intermetallic compounds, research on the manufacture, evaluation, and utilization technology of such materials.

5. Research concerning invention of special powders and clarification of their characteristics.

Along with the establishment of basic technology concerning the manufacture of highly purified powders in the centrifugal spray method and liquid spray method and of composite very fine particles in the rapid cooling solidification method and liquid phase method, a clarification of the special powder characteristics obtained by these.

6. Research concerning material life forecasting knowledge.

Comprehensively systematize fact data and scientific and empirical knowledge concerning the life of materials and establish a technology base to simulate theoretically the life of materials.

#### Other Ministry/Agency Funded Research

Independent or shared research with funds of ministries or agencies other than the Science and Technology Agency was conducted on the following three topics.

##### 1. Research and development of composite materials.

The objective is to set up from the aspect of matrix improvement methods to inhibit reactions of matrix metals and fibers in fiber reinforced metal base composite materials.

##### 2. Research and development of high performance crystal control alloys.

Since the 1980's, the development of metal materials superior in heat resistance, toughness, and corrosion resistance has been necessary for the development of technical leading edge industries (such as aerospace and energy).

The aim of this research is the development of alloys which have performance surpassing the properties of existing alloys through the high control of metal texture, as well as their evaluation and serviceability.

##### 3. Research concerning the development of $\text{SO}_x$ and $\text{NO}_x$ solid electrolyte sensors.

The synthesis of solid electrolytes which have the function of being able to differentiate selectively  $\text{SO}_x$  and  $\text{NO}_x$  in an attempt to advance the measurement technology for  $\text{SO}_x$  and  $\text{NO}_x$  which are atmosphere pollutants, and development of a solid electrolyte sensor incorporating these. In addition, a basic study concerning calcogen compound synthesis methods and their numerous electrochemical properties.

#### Special Joint Government and Private Research

Research was conducted with science and technology promotion funds on the following topic for the efficient promotion of joint research on a large research scale in an attempt for exchange of research with private enterprise:

Research concerning manufacturing technology of high performance superconducting materials.

Expansion of continuous melt fast cooling method development at NRIM and along with making wire out of third generation superconducting materials, the stable demonstration of performance by control of micro structure and acquisition of superconducting wire appropriate for applications in various kinds of superconducting apparatus. Also, development of manufacturing technology for oxide group superconducting materials by gas rapid cooling method.

#### Research and Development of Superconducting Materials (Superconducting materials research multi core project)

In order to accelerate the research and development of new superconducting substances, NRIM conducted research on the following 13 topics, which were assigned centering on six cores, the theory core, data base core, raw materials control core, thin film core, composite processing core, and superconducting performance evaluation core, based on the superconducting materials research multi core project which promotes research and development with the cooperation of industry, academia, and government, making use of the research potential accumulated by related research institutions.

##### 1) Theory Core

Theoretical research concerning the electronic structure and superconducting mechanism of high temperature superconducting substances.

Along with clarifying the electronic structure to explore the uniqueness of high temperature superconducting substances, the aim is to explore the construction of theoretical models and clarify the superconducting mechanism by evaluation and analysis of the superconducting properties deduced from the models.

##### 2) Data Base Core

Construction of a data base for development of new superconducting materials.

Compile metadata in order to make a data base with data reported concerning new superconductors as fact data, as well as construct the data base. Also, conduct research on a utilization system for access by general users.

Research concerning superconduction application trends.

Grasp the key points by conducting a survey on application trends for new superconducting materials, set up a future research and development guide, and contribute to the study of social and economical countermeasures.

##### 3) Raw Materials Control Core

Research concerning highly purified active metals for superconducting raw materials.

Contribute to high performance superconducting materials by development of various kinds of refining technology for making highly purified metals.

Research concerning numerous properties of superconducting materials raw material powders for high pressure forming.

Attempt to establish a technology base for manufacturing oxide superconducting materials and their raw materials by ceramic raw material manufacturing technology, isostatic pressure forming technology (CIP), and isostatic pressure sintering (HIP).

Research concerning manufacture of composite oxide very fine powders for superconducting materials.

Conduct a basic study concerning manufacture of composite very fine powders and manufacture of sintered bodies using them for oxide superconductors.

Research concerning powder manufacture for superconducting materials by the melt rapid cooling solidification method.

Establish of technology base for manufacture of raw material powders with little segregation containing alkaline earth metals and rare earths as well as compounds of these using the melt rapid cooling solidification method.

#### 4) Thin Film Core

Research concerning thin films of oxide superconductors applying reaction lamination technology.

Establish technology for manufacturing thin film by low temperature and precision synthesis, preventing defects and damage of the superconducting thin film while controlling the crystal structure and oxygen amount in order to make new superconducting substances serviceable as high speed operation elements (Josephson element), highly sensitive magnetic sensors, and VLSI substrate material.

#### 5) Composite Processing Core

Basic research concerning special wire technology for superconducting materials.

Research and development concerning new, special manufacturing technology to make composite wire and tape of high temperature oxide superconducting materials and attempt to make high performance wire.

Research concerning new superconducting tape technology by gas reaction method.

Attempt to make tape-shaped wire serviceable using the gas method which is superior in texture controllability as well as crystal orientation controllability because the superconducting property of Bi group and Y group high temperature oxides depends strongly on crystal composition structure anisotropy.

Research concerning manufacturing technology for new superconducting materials by chemical reaction.

Conduct research concerning wire technology combining raw material manufacture by the sol and gel methods

and heat treatment by laser irradiation for oxide superconductors anticipating development of new manufacturing technology.

Research concerning wire technology for new superconducting materials by solid and liquid reaction methods.

A study concerning the possibility of making wire and tape by applying solid methods using diffusion reactions and precipitation reactions and liquid methods using solidification and consolidation phenomena from melted liquids and solutions to synthesis of high temperature oxide superconductors.

#### 6) Superconduction Performance Evaluation Core

Development of super strong magnetic field magnet.

Development of an 80T class long pulse magnet, 40T class hybrid magnet, 20T class large aperture superconducting magnet and measuring device for magnetic properties in a super precise magnetic field in order to clarify superconducting properties of new superconducting substances, and multi-faceted evaluation of the properties of new superconducting substances.

As indicated above, while NRIM is giving priority to this necessary research as project research in order to contribute to the solution of numerous problems concerning metal materials demanded by various wide-ranging and diverse technical fields, it is actively conducting ordinary research seeking sources for the future, upgrading the scholastic and technical level of NRIM, and striving for the smooth promotion of project research.

In establishing these research topics, consultations were made with the Steering Committee (comprised of men of learning and experience from universities, academic societies, industrial circles, and research institutions) stipulated by the organization regulations of NRIM, and by reflecting the proposals, suggestions, and desires of the Steering Committee, efforts are made for the effective conduction of research which meets social needs.

Furthermore, in comprehensively and professionally tackling research, with regard to test research in special fields such as nuclear power materials, aerospace development materials, and superconducting materials, where there is a need for it to be conducted systematically, a Nuclear Power Research Committee and Superconducting Materials Research Committee have been respectively established within NRIM, surveys and discussions are conducted concerning setting up research programs and promoting research, and efforts are made for the efficient conduction of research and promotion of a critical mind.

Also, to make a contribution as an institute widely open to the society, in the future it will expand joint research conducted between private enterprises, universities, and national test research institutions, maintain joint research equipment and facilities, substantially invite visiting researchers to promote research exchanges, and

aggressively conduct the appointment and invitation of foreign researchers as well as exchange of personnel with industrial circles.

For the smooth promotion of this research work, it is necessary to have a research support system making free use of brand new equipment and advanced technology with regard to the manufacture of test materials,

assembly of devices, various kinds of analysis and various kinds of tests in the course of advancing research. For this purpose, various related research departments and the Technology Section of the Management Department will provide technical services concerning physical analyses, chemical analyses, smelting and rolling, various kinds of construction, low temperature tests, material tests, and computer use.

Table of Research Topics

Summary of Research Topics		
* = New topic		
Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept./Research Group	Chief Researcher
1. Research concerning development of intermetallic compound materials for high performance luminous elements	Surface/Interfacial Control Research Dept.	Nobuyuki Oguchi
2. Basic research concerning non-contact evaluation methods for materials by laser beam	Damage Mechanism Research Dept.	Tetsuya Saito
3. Research and development of apparatus materials using ultra low temperatures	1st Research Group	Hiroshi Maeda
4. Research concerning development of lightweight, heat resistant intermetallic compound materials	3rd Research Group	Tokuzo Tsujimoto
Nuclear Power Research (10 Topics)		
1. Research concerning development of high performance intermetallic compound materials for nuclear power	Mechanical Properties Research Dept.	Morihiro Nakamura
2. Research concerning corrosion resistance of nuclear fuel reprocessing device welded parts	Texture Control Research Dept.	Harukata Nakamura
3. Research concerning evaluation of low temperature brittleness of metal materials used in nuclear fuel transport containers	Environmental Performance Research Dept.	Takashi Yasunaka
4. * Research concerning evaluation of corrosion resistance of artificial barrier materials in stratum disposal	Environmental Performance Research Dept.	Toshiaki Kodama
5. Research concerning properties of new superconducting wire for nuclear fusion reactors	1st Research Group	Hitoshi Wada
6. Research concerning low induced radioactive materials	2nd Research Group	Tetsuji Noda
7. * Research concerning technology for in situ analysis and evaluation of nuclear irradiation damage	2nd Research Group	Kazuo Furuya
8. * Research on material strength and life forecasting technology under an irradiation environment using an ion beam	2nd Research Group	Shiromasa Nagakawa
9. * Research concerning advanced evaluation of damage and life of structural materials for high temperature gas reactors	2nd Research Group	Tatsuhiko Tanabe
10. Research concerning corrosion fatigue—stress corrosion crack interaction of metal materials for light water reactors	5th Research Group	Norio Nagata
Material Strength Data Sheet (2 Topics)		
1. Compilation of Fatigue Data Sheet (III)	Damage Mechanism Research Dept.	Satoshi Nishijima
2. Compilation of Creep Data Sheet (III)	Environmental Performance Research Dept.	Senshu Tanaka
Science and Technology Promotion and Coordination Funded Research (17 Topics)		
General Research		
1. Research concerning basic technology on the development of gradient functional material for thermal stress relaxation	Functional Properties Research Dept., Texture Control Research Dept.	Ichiro Shioda
2. Research concerning knowledge base system for support of chemical substance design	Materials Design Research Dept.	Michio Yamazaki
3. Research concerning clarification of physical, chemical, and biological phenomena under a microgravity environment through international cooperation	Materials Design Research Dept., Functional Properties Research Dept., 1st Research Group, 4th Research Group	Michio Yamazaki

## Summary of Research Topics

\* = New topic

Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept./Research Group	Chief Researcher
4. Research concerning basic technology for the invention of new functions through highly purified rare metals	Reaction Control Research Dept., Basic Physical Properties Research Dept.	Shiro Yoshimatsu
5. Research concerning basic technology for invention of new materials by hybrid structural design technology (II)	Surface/ Interfacial Control Research Dept., Basic Physical Properties Research Dept., Functional Properties Research Dept.	Keiichi Ogawa
6.* Research concerning development of ultra high vacuum generation, measurement, and utilization technology	Surface/ Interfacial Control Research Dept.	Kazuhiro Yoshihara
7. International joint research concerning new materials test evaluation technology	1st Research Group, Surface/Interfacial Control Research Dept., Environment Performance Research Dept., Materials Design Research Dept., 3rd Research Group, Texture Control Research Dept., Damage Mechanisms Research Dept.	Hiroshi Maeda
8. Research concerning development of ultra high temperature generation, measurement, and utilization technology (II)	4th Research Group	Masanari Ozawa
Priority Basic Research		
1.* Basic research concerning micro composite technology used in CVD methods	Materials Design Research Dept.	Takehiko Sakagaki
2.* Basic research concerning technology for invention of semiconductor quantum well fine lines	Surface/Interfacial Control Research Dept.	Nobuyuki Oguchi
3.* Basic research concerning clarification of unique electrical conductivity change mechanisms in thin film surfaces by ion beam method	Surface/Interfacial Control Research Dept.	Kazuo Saito
4.* Research concerning analysis of composite material deformation and fracture behavior with supersonic wave microscope	Measurement Control Research Dept.	Senri Masuda
5.* Research concerning material damage element process measurement and clarification with electron beam lithography	Damage Mechanisms Research Dept.	Tsunao Niitani
6.* Research concerning manufacture of intermetallic compounds by combustion synthesis method	3rd Research Group	Yoshinari Umieda
Important Individual Joint International Research		
1* Research concerning gallium gasification extraction properties	Reaction Control Research Dept.	Shiro Yoshimatsu
2.* Research concerning super strong magnetic field magnets	1st Research Group	Hiroshi Maeda
Urgent Commissioned Research		
1.* Urgent research concerning manufacture as well as forming and sintering of aluminum alloy fine powder by high pressure liquid spray method	4th Research Group	Tetsu Takeda
Directed Research (6 Topics)		
1.* Research concerning titanium alloy toughness mechanism and upgrading properties	Mechanical Properties Research Dept.	Tadao Kainuma
2. Research concerning gallium and other valuable metal extraction technology	Reaction Control Research Dept.	Akira Fukuzawa
3.* Research concerning plasma resistance and irradiation resistance properties of nuclear fusion reactor first wall material	2nd Research Group	Harushige Shiraishi
4.* Research concerning invention of functional intermetallic compounds and evaluation of properties	3rd Research Group	Tokuzo Tsujimoto
5.* Research concerning invention of special powders and clarification of their characteristics	4th Research Group	Atsushi Oguchi
6.* Research concerning material life forecasting knowledge	5th Research Group	Tomoyuki Takeuchi
Other Ministry/Agency Funded Research (3 Topics)		



Summary of Research Topics

\* = New topic

Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept./Research Group	Chief Researcher
1. Research and development of composite materials	Functional Properties Research Dept.	Ichiro Shioda
2. Research and development of high performance crystal control alloys	Materials Design Dept.	Michio Yamazaki
3.* Research concerning the development of SO <sub>x</sub> and NO <sub>x</sub> solid electrolyte sensors	Reaction Control Research Dept.	Tsutomu Morinaka
Special Joint Government and Private Research (1 Topic)		
1. Research concerning manufacturing technology of high performance superconducting materials	1st Research Group	Hiroshi Maeda
Multi Core Project Research (13 Topics)		
Theory Core		
1.* Theoretical research concerning the electronic structure and superconducting mechanism of high temperature superconducting substances	Basic Physical Properties Research Dept.	Tamio Oguchi
Data Base Core		
1.* Construction of a data base for development of new superconducting materials	Materials Design Research Dept.	Yuji Asada
2.* Research concerning superconduction application trends	Materials Design Research Dept.	Kenichi Hoshimoto
Raw Materials Control Core		
1.* Research concerning highly purified active metals for superconducting raw materials	Reaction Control Research Dept.	Ryosuke Hasegawa
2.* Research concerning numerous properties of superconducting materials raw material powders for high pressure forming	3rd Research Group	Yoshinari Umieda
3.* Research concerning manufacture of composite oxide very fine powders for superconducting materials	4th Research Group	Masanari Ozawa
4.* Research concerning powder raw materials manufacture for superconducting materials by the melt rapid cooling solidification method	4th Research Group	Komei Harada
Thin Film Core		
1.* Research concerning thin films of oxide superconductors applying reaction lamination technology	Surface/Interfacial Control Research Dept.	Keikichi Nakamura
Composite Processing Core		
1.* Basic research concerning special wire technology for new superconducting materials	1st Research Group	Hiroshi Maeda
2.* Research concerning tape technology for new superconducting materials by gas reaction method	1st Research Group	Yoshiaki Tanaka
3.* Research concerning manufacturing technology for new superconducting materials by chemical reaction method	1st Research Group	Hitoshi Wada
4.* Research concerning wire technology for new superconducting materials by solid and liquid reaction methods	1st Research Group	Kazumasa Tokano
Superconduction Performance Evaluation Core		
1.* Development of super strong magnetic field magnet	1st Research Group	Hiroshi Maeda
Ordinary Research (49 Topics)		
Research Topics	Research Office in Charge	Chief Researcher
Basic Physical Properties Research Dept.		
1. Research concerning synthesis process of artificial substances by computer simulation	1st	Tamio Oguchi

## Summary of Research Topics

\* = New topic

Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept/Research Group	Chief Researcher
2. Research concerning electron state for rare earth layer compounds under high pressure	2nd	Takehiko Matsumoto
3. Research concerning conductivity of solids and surface activity	3rd	Makoto Okawachi
4. Research concerning distribution of alloy elements in diffusion phase transformation and kinetics	4th	Masato Enomoto
5.* Research concerning synthesis and properties of intermetallic compounds having strong electron correlation	1st	Haruyoshi Aoki
6.* Research concerning computer tests of amorphous generation process with solid reactions	4th	Katsuyuki Kusu
Functional Properties Research Dept.		
1. Research concerning steel shape memory effects and their serviceability	1st	Yoshio Kajiware
2. Research concerning oscillation inhibiting materials	1st	Koji Kawahara
3. Research concerning functional alloys manufacture and their numerous characteristics by gaseous diffusion infiltration process	2nd	Hisatomo Sasano
4. Research concerning synthesis and properties of very thin fiber structure metals	3rd	Tsutomo Nakatani
5. Research concerning detection of functional properties by gradient composition	5th	Ichiro Shioda
6.* Research concerning alloy film for hydrogen separation	4th	Muneyoshi Amano
Mechanical Properties Research Dept.		
1. Basic research concerning coexistence in ferrite steel liquid metals	2nd	Tadashi Suzuki
2. Research concerning fatigue properties of metal carbides and oxides	3rd	Susumu Horibe
3.* Research concerning upgrading abrasion fatigue properties	4th	Masamori Tsunoda
Materials Design Research Dept.		
1. Research concerning tungsten fiber reinforced heat resistant alloy composite design technology	4th	Takashi Arai
2.* Research concerning extraction and systemization of knowledge for materials design	1st	Kenichi Hoshimoto
Reaction Control Research Dept.		
1. Reaction engineering research on continuous reaction process	1st	Akira Fukuzawa
2.* Basic research concerning new synthesis technology with phthalocyanine mixes	2nd	Hiroaki Isagane
3.* Basic research concerning synthesis and reciprocal separation of metal chlorides	4th	Koji Kamiya
Surface/Interfacial Control Research Dept.		
1. Basic research concerning transition process in magnetic bodies and superconductors at ultra low temperature	2nd	Mitsuru Uehara
2.* Research concerning diffusion phenomena of substances in structure controlled thin films	1st	Kazuhiro Yoshihara
3.* Basic research concerning surface and interfacial microscopic structure control and electron physical properties	4th	Kazuo Saito
Texture Control Research Dept.		
1. Texture control research using different phase mixed states	2nd	Tamotsu Tanto

Summary of Research Topics

\* = New topic

Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept/Research Group	Chief Researcher
2. Research concerning manufacture and application of tungsten monocrystals	2nd	Tadayuki Fujii
3. Research concerning heating and melting behavior with arcs	3rd	Akira Okada
4. Research concerning beam mode of high density energy beam for metal processing	5th	Hirosada Irie
5.* Research concerning invention of unidirectional solidified texture materials	1st	Akira Sato
6.* Research concerning solidification control of heterogeneous smelting and solidification	1st	Goro Omori
7.* Research concerning analysis of interfacial element reactions in interfacial joining	3rd	Ken Sasagibe
8.* Research concerning film formation phenomena with particle deposition	4th	Seiji Kuroda
Measurement Analysis Research Dept.		
1. Research concerning analysis method for hybrid selection rules	1st	Eiichi Furubayashi
2. Research concerning evaluation of machinability of high hardness materials	1st	Hiroto Nakajima
3. Research concerning low alloy steel hydrogen erosion structure	1st	Hiroto Nakajima
4. Research concerning digital graphic processing of X-ray microanalyzer	2nd	Masatoshi Fukamachi
5. Research concerning measurement and analysis technology for fracture element process of fiber reinforced composites	2nd	Senri Masuda
6.* Research concerning development of chemical measurement methods using plasma	1st	Morimasa Saito
7.* Research concerning establishment of analysis methods accompanying development of metal materials	4th	Haruno Okawachi
8.* Research concerning advancement of metal material physical analysis methods	3rd	Yoshio Tamura
Damage Mechanism Research Dept.		
1. Research concerning non-destructive material evaluation methods	4th	Tetsuya Saito
2.* Research concerning changes in fatigue damage generation mechanism based on slip differences	1st	Koji Yamaguchi
3.* Research concerning clarification of damage process with electron beam lithography	2nd	Tsunao Niitani
4.* Research concerning control of high temperature damage and life extension**	2nd Damage, 2nd, 3rd Environment	Tsunao Niitani
Environmental Performance Research Dept.		
1. Research concerning behavior of newly generated surfaces in fatigue fractures	1st	Saburo Matsuoka
2. Research concerning evaluation methods for structural steel strength limitations in stress corrosion environment	2nd	Takao Aoki
3. Research concerning evaluation of corrosion resistance of metal materials for electronic apparatus and structures	4th	Toshiro Fukushima
4.* Basic research concerning control of environment fatigue crack generation with surface films	2nd	Kenji Kanazawa
5.* Research concerning evaluation of crack generation and growth behavior under high temperature static loads and repeated loads	3rd	Koichi Yagi

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**Summary of Research Topics**

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\* = New topic

Project Research		
Special Research (4 Topics)		
Research Topic	Related Research Dept/Research Group	Chief Researcher
6.* Research concerning evaluation of environmental fatigue crack propagation properties in vicinity of joined interfaces	5th	Akihiko Ota

\*\* Comprehensive research, other = general research.

Survey Research (2 Topics)		
Research Topic	Related Research Dept/Research Group	Chief Researcher
1. Survey research concerning metal materials for biological uses	4th Functional	Haruo Sasaki
2.* Survey research concerning space shuttle and its materials	2nd, 3rd, 4th Design, 5th Functional, 2nd Measurement, 2nd Environmental, 2nd Third Group	Michio Yamazaki

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